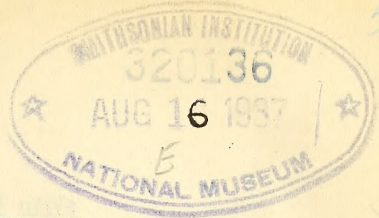# ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

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LIST OF ILLUSTRATIONS

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS. FAMILY SERRIVOMERIDAE.
PART I: GENUS *SERRIVOMER*.

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

VOLUME XX.   NUMBERS 1 AND 2

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

No. 1—Family DERICHTHYIDAE

No. 2—Family NESSORHAMPHIDAE

William Beebe

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

FAMILY DERICHTHYIDAE[1]

WILLIAM BEEBE

(Figs. 1-9 incl.)

CONTENTS

INTRODUCTION

For detailed data of nets, locality, dates, etc., concerning the capture of the deep-sea eels treated in this monograph, refer to ZOOLOGICA, Vol. XIII, Nos. 1, 2 and 3, and for physical data, methods of measurement and definitions of growth stages see ZOOLOGICA, Vol. XVI, No. 1. The accounts of deep-sea fishes directly preceding the present paper comprise ZOOLOGICA, Vol. XVI, Nos. 2, 3 and 4. Reports on the other families of eels are approaching completion and will appear shortly, together with a survey of the Order and a complete résumé of present knowledge of the evolution of deep-sea eels.

All the material under consideration was taken in the course of 1,350 nets drawn in one locality, an eight-mile circle, with its

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[1] Contribution No. 478, Department of Tropical Research, New York Zoological Society.

Fig. 1. *Derichthys serpentinus.* A photograph of the head of an adult female, showing pores and striations. (x 2.6).

center at 32° 12′ North Latitude and 64° 36′ West Longitude, nine and a quarter miles south-southeast of Nonsuch Island, Bermuda. Vertically this is an imaginary cylinder, considered as extending from the surface to the bottom of the sea, an extreme range of 1,500 fathoms. Six silk metre-nets were used, strung at exact intervals along two miles of wire, drawn at an angle of 30 degrees, at the rate of two knots an hour.

In the present work I have had the cooperation of my entire staff. Mr. John Tee-Van supervised the capture of the deep-sea fish. Miss Gloria Hollister cleared and stained specimens for osteological study. Miss Jocelyn Crane's part in these papers is rather that of co-author than of an able assistant; I owe to her the elaboration of the great mass of details. The drawings are the work of Mr. George Swanson.

FAMILY DERICHTHYIDAE Gill 1884

Body anguilliform, slender; anus before or behind midbody; scales absent, skin smooth; lateral line distinct; head

oblong, oval; eyes in anterior part of head, well developed; nostrils dorso-lateral or lateral, neither pair tubular; mouth with cleft little oblique, extending at least to posterior part of eye; jaws strong; maxillaries flattened, firmly articulated with the expanded pre-vomer; teeth conical, on jaws and vomer; branchial apertures small, lateral or oblique slits in front of or below pectorals, well separated; dorsal commencing behind head; anal origin before or behind middle of body; caudal, when present, confluent with dorsal and anal; membranes of vertical fins thick. Trewavas (1932, p. 641) has shown that the structure of the upper jaw in *Derichthys* is essentially similar to that of other eels, definitely abolishing the order Carencheli. Three genera.

Key to the Genera

A.   Anal origin at or behind middle of body, far behind dorsal origin (deep-sea, Atlantic) ....*Derichthys* Gill 1884

AA. Anal origin well in advance of middle of body, slightly behind dorsal origin.

    B.   Caudal fin present (deep-sea, Philippines)
                                          Benthenchelys Fowler 1934

    BB. Caudal fin absent (shallow water, Panama)
                                Gorgasia Meek & Hildebrand 1923

Genus **Derichthys** Gill 1884

With the characteristics of the family. A neck-like constriction between head and pectoral fins; anus sub-median, slightly behind middle of body; dorsal, anal and caudal confluent.

It seems almost certain that only one of the three described species is valid. I agree with Parr (1934 p. 33 ff.) that there is no reason for maintaining *D. iselini* Borodin 1929 as distinct from *D. serpentinus*. As Parr points out, there is not one of the so-called differences between the species which cannot properly be laid to the incomplete descriptions and bad preservation of the type of *D. serpentinus*, while the terminal, tubular "nostrils" of *D. iselini* are unquestionably merely sensory pores in advance of the true anterior nostrils. They are very prominent in all the Bermuda specimens.

Fig. 2. The geographic and vertical distribution of *Derichthys serpentinus*. The relative number of specimens taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the left of the column which gives the vertical range of the genus.
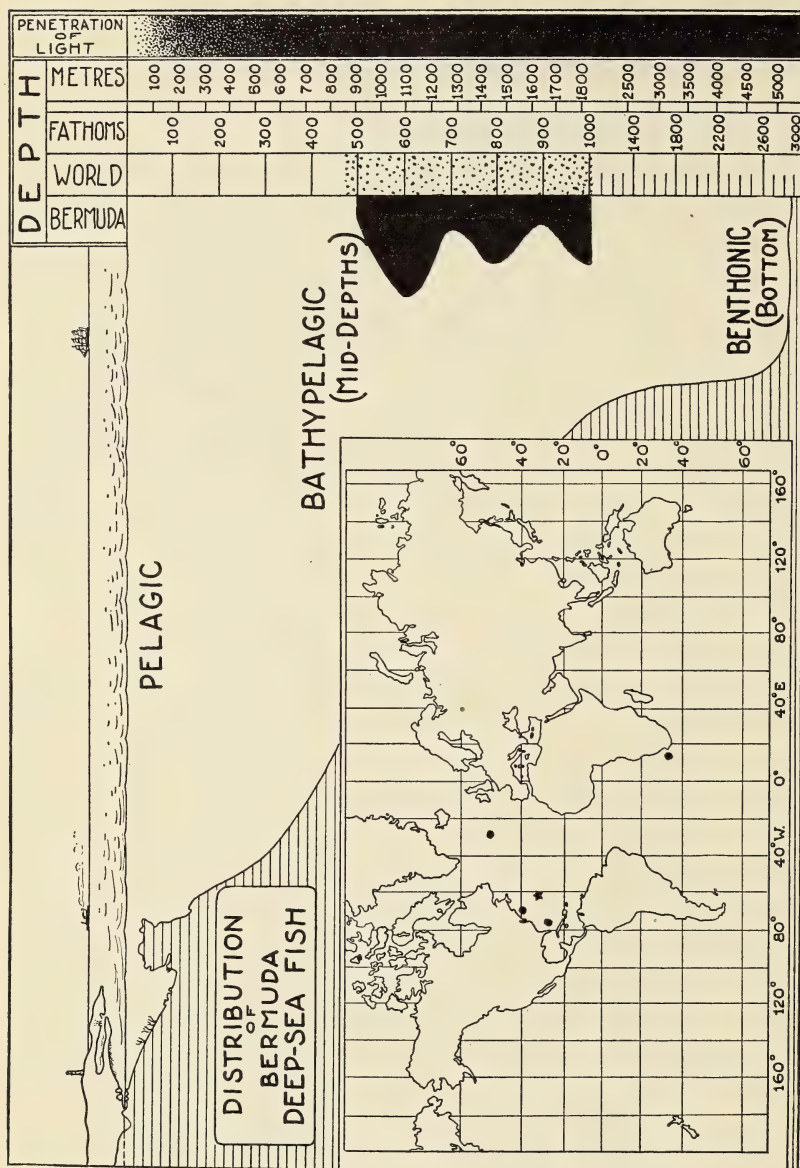
In addition I am synonymizing *D. kempi* (Norman 1930) with *D. serpentinus,* as our Bermuda examples agree perfectly, except for the unpaired frontals (see p. 9), with the descriptions and figures of the specimen from the South Atlantic.

Derichthys serpentinus Gill 1884

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Eighteen specimens; June to September, 1929 to 1931; 500 to 1,000 fathoms; from a cylinder of water eight miles in diameter (five to thirteen miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 55 to 268 mm.

SPECIMENS PREVIOUSLY RECORDED

Four specimens; 1,000-0 fathoms; West Indies, North Atlantic and South Atlantic off Cape Town; recorded standard lengths from 160 to 200 mm. (Fig. 2).

DESCRIPTION OF ADULT

COLOR (fresh specimens) : (Figs. 1, 3C, 4C). Tawny olive to mouse gray, with glints of bluish sheen on the neck; fins lightly pigmented but almost transparent; midway of each web in the largest specimens is an oval, opaque, whitish patch, possibly luminous; these patches are invisible in preserved fish.

PROPORTIONS: Depth in length 16.5 to 22; head in length 6.5 to 8.5; head minus neck[2] in length 11.3 to 15; eye in head 7.3 to 8.8 (covered by skin) ; eye in head without neck 4 to 5.2; snout in head 5.5 to 6.5; snout in head minus neck 3.2 to 3.6; snout to dorsal origin in length 3.8 to 4; snout to anal origin in length 1.8 to 1.9.

TEETH: Small, conical, in three to five irregular rows on both jaws, dying out posteriorly. The pre-vomerine band is continuous with that of the maxillary, and also consists of three to

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[2] Neck measured from first lateral line pore to posterior end of gill-slit.
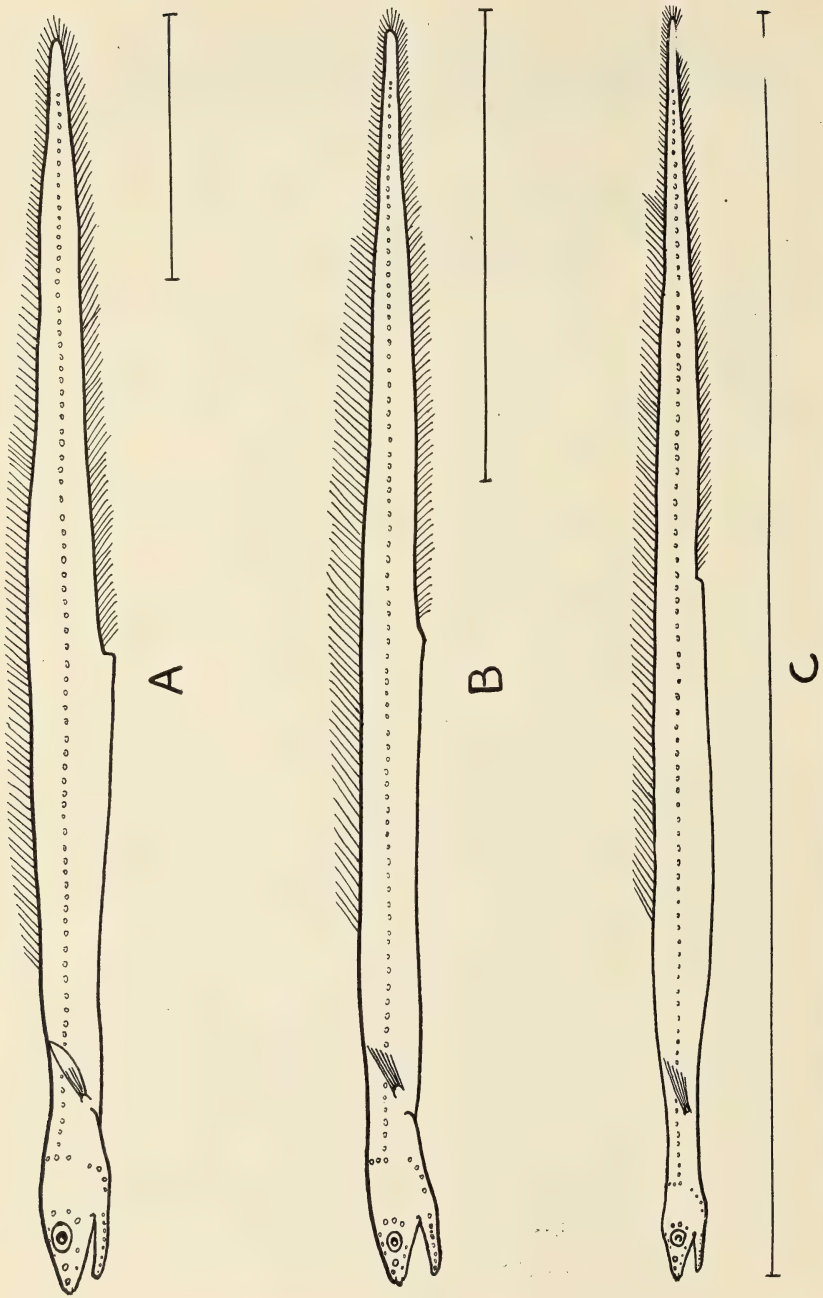
Fig. 3. *Derichthys serpentinus.* A, adolescent, 58 mm.; B, transitional adolescent, 98 mm.; C, adult, 268 mm. The relative size of the specimens is indicated by the straight lines.
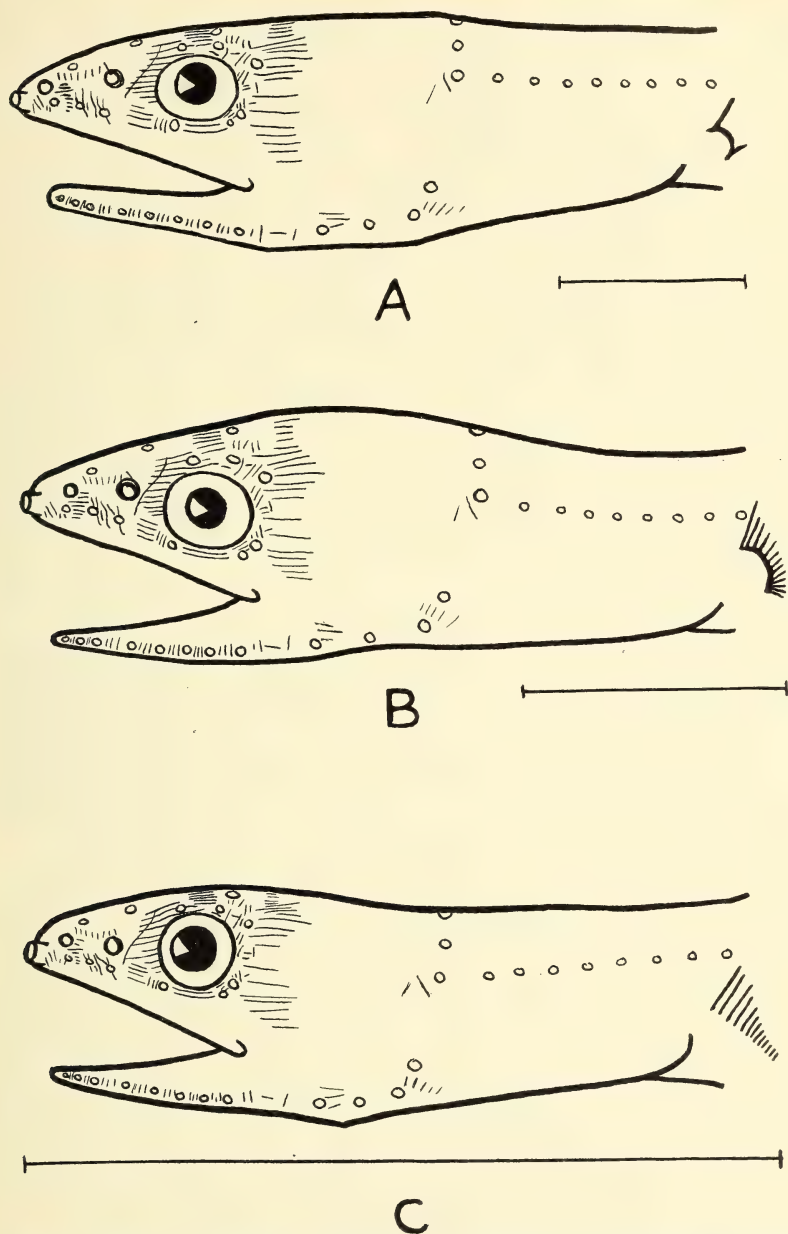
Fig. 4. Heads of *Derichthys serpentinus*. A, adolescent, standard length 58 mm.; B, transitional adolescent, standard length 98 mm.; C, adult, standard length 268 mm. The relative size of the specimens is indicated by the straight lines.

five rows. There is a horseshoe-shaped group on the vomer proper, separated from the pre-vomerine group; the horseshoe is composed of an anterior mass of about a dozen teeth, the inner ones sometimes rudimentary, and two posteriorly directed rows of five to ten teeth each.

FINS: Pectoral 13, slightly longer than the combined lengths of snout and eye. Dorsal 226 to 256, originating at a point about one-fifth of the length of the fish from snout; the posterior dorsal rays, occupying about the last third of the caudal peduncle, are abruptly shorter, less than half as long as the others. Anal 155 to 180, beginning at or immediately behind the middle of the body, its rays much shorter than the anterior dorsal rays. Caudal short, less than diameter of eye, rounded, confluent with dorsal and anal; 10 true caudal rays.

NOSTRILS: Both nostrils are situated dorso-laterally, dividing the snout into almost equal thirds; the posterior one is about a third again as large as the anterior.

PORES AND LATERAL LINE: On the head the pores are arranged in the following characteristic manner: Tip of snout, one pair, very large, tubular, directed forwards or slightly upwards (this was mistaken for a pair of nostrils in the type description of *Derichthys iselini*); above each anterior nostril, two small pores; below same, one small pore; on each side of snout profile, above posterior nostrils, one pore, moderate; above each orbit, three; on each side of top of crown near level of posterior border of eye, one; on each side of snout, behind anterior nostril, two; below anterior corner of orbit, one; below posterior corner of orbit, two; along mandible to end of gape, eight; continuing this line posteriorly to level of lateral line origin, four, the fourth above and slightly behind the third; between the first lateral line pores of each side, extending dorsally along the boundary between head and neck, three (one being median). In addition to these pores, the head is also conspicuously marked with equally characteristic groups of embossed striations. The lines of each group are parallel, some groups being horizontal, some vertical; usually there are six or seven lines in a group (Fig. 4). The most posterior groups are located close behind the eye, with the exception of an inconspicuous series a short distance behind the pectorals. The striations are probably associated with

the lateral line system. The lateral line begins at the same level as the "neck," well in front of the pectoral. For a short distance it runs near the dorsal profile, but soon descends to the mid-line, which it subsequently follows. There are 80 to 90 pores, all slightly tubular, stopping at a little more than a head's length in front of the caudal base. The course of the lateral line between the pores can be traced by a prominent ridge.

MYOMERES AND VERTEBRAE: 126 to 130.

BRANCHIOSTEGALS: 7.

OSTEOLOGY: The general skeletal characters of *Derichthys* may be summarized as follows: An expanded, dentigerous pre-vomer united with the vomer by a narrow isthmus; frontals fused or ankylosed; supraoccipital present; palato-pterygoid slender, vestigial; four pectoral radials; ribs absent; caudal vertebrae without lateral transverse processes in addition to the haemal arches. The following detailed description is derived from a cleared and stained adult female, 268 mm. long, in the Bermuda collection.

The entire skeleton is fairly well ossified with the exception of the posterior rays of the vertical fins and the major part of the vertebral column. Only toward the tip of the tail do the centra show more than faint traces of stain. These last vertebrae, however, along with the jaws and components of the hyoid and branchial arches, are the most strongly ossified bones in the body.

Skull: (Fig. 5). Although the skull has not taken up much of the scarlet stain, still it is unquestionably well ossified, as it is very firm. The most striking characteristic of the skull and of the entire head as well is the prevalence of consolidated bones. The frontals are ankylosed; the hyomandibular, quadrate and preopercle are fused to form a single unit, and there is no hint of a separate articular or angular.

Unlike Trewavas's specimen from South Africa (Trewavas, 1932, p. 641), in which the frontals were united by suture, in all three of the cleared Bermuda specimens they are firmly anky-losed together, without a sign of division. They extend forward almost as far as the anterior margin of the orbit, and then bend downward behind the ethmoid, dying out just above the vomer itself. The parietals are more than equal to the frontals in area,
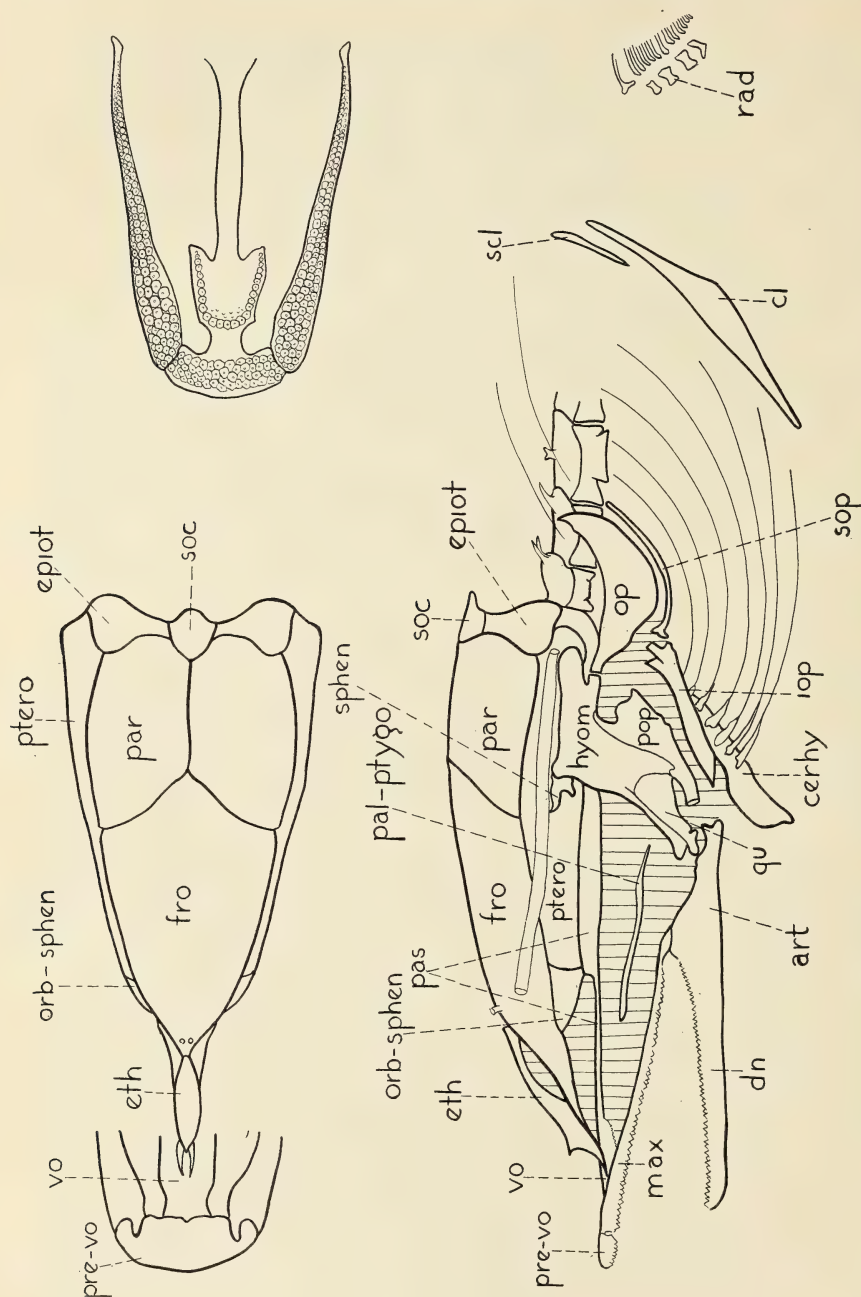
Fig. 5. *Derichthys serpentinus.* Bones of the head of adult female, standard length 268 mm. Upper left, dorsal view of skull; upper right, ventral view of upper jaw; lower, lateral view of head. (All x 5).
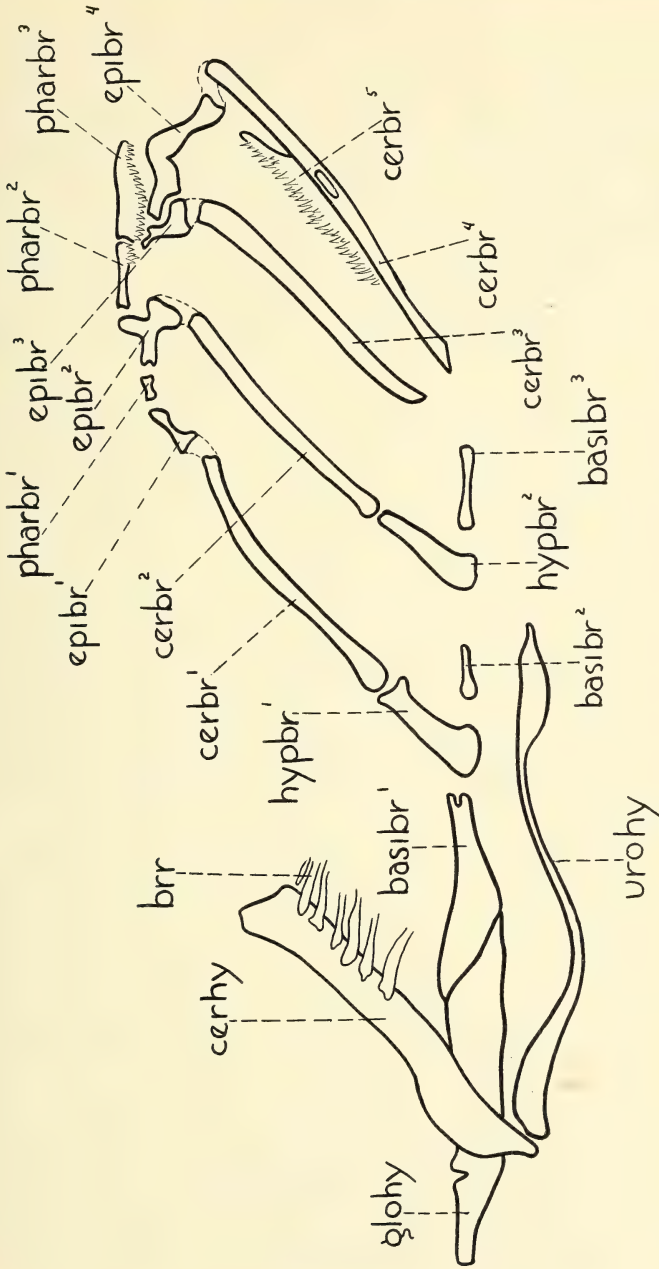
Fig. 6. *Derichthys serpentinus.* Hyoid and branchial arches of adult female, standard length 268 mm. (x 8.6).

though the epiotics, posterior to these, are only slightly larger than the tiny supraoccipital. The elongate pterotics, laterally placed, extend the full length of the parietals and more than half that of the frontals. Anterior to the pterotics are the triangular orbito-sphenoids. Below, the posterior half of the parasphenoid, much broadened, forms the anterior part of the floor of the brain-case, the unusual length of this bone and of the pterotic being necessitated by the forward position of the eye in connection with the elongation of the jaw. This also brings about the unusual separation of the orbito-sphenoid and the sphenotic, which is located slightly behind the junction of the frontal and parietal.

Palato-pterygoid Arcade: (Fig. 5). The hyomandibular is much fenestrated, and fused firmly with both the quadrate and preopercle. The upper anterior arm is short, articulating only a little behind the vertical from the anterior edge of the epiotics; a short projection from the ventral margin of the arm articulates with the opercle; the third arm, directed antero-ventrally, is fused to the inner face of the quadrate, only a rim of the bone projecting above it; this arm extends almost to the jaw angle. The quadrate, articulating with the undifferentiated angular, is short, and broad posteriorly. The palato-pterygoids, although well ossified, are of needle-like slenderness and seem to serve very little practical use as they do not connect directly with any bone.

Jaw Apparatus: (Fig. 5). The jaws and teeth are the most strongly ossified elements in the body. The "praemaxillary region of the praemaxilla-ethmo-vomer" of Trewavas (1932 p. 641) may be termed more conveniently the pre-vomer. In her specimen of 160 mm. from South Africa this bone is "united with the ethmo-vomerine region by a narrow isthmus." In Bermuda specimens both larger and smaller than hers, this isthmus, though very distinct, is unstained. The pre-vomer forms the entire front of the broad, obtuse snout and articulates with the maxillaries in close-fitting joints, a pair of grooves in the dorsal surface of the pre-vomer receiving a projection from each maxillary. The latter show broad ventral surfaces anteriorly, holding several rows of teeth; posteriorly, however, they are much attenuated. They reach well behind the posterior border of the

eye. The vomer proper is oblong, with the moderately broad, flat parasphenoid arising from its excavated posterior border. To its dorsal surface the forked end of the ethmoid is firmly attached by suture, and not ankylosed as in Trewavas's specimen. The ethmoid extends upward and backward, arching in its posterior part to form a foramen with the frontal, which it overlies throughout its length. The lower jaw is considerably shorter than the upper and about twice as deep, and extends a full third of its entire length behind the end of the maxillary. There are no lines of demarcation into articular and angular.

Opercular Apparatus: (Fig. 5). The preopercle is completely separated from the rest of the series, being fused to the ventral side of the hyomandibular by a large thin flange arising from the antero-dorsal side of the typically tubular portion of the bone. The interopercle is an elongate bar free from both preopercle and subopercle. The latter is very slender and almost crescentic, lying immediately beneath the horizontally placed opercle and following its curving outline. The opercle reaches the vertical from the middle of the second vertebra.

Hyoid Arch: (Fig. 6). There is no trace of an interhyal, and the epihyal and hypohyal elements are invisibly consolidated in the ceratohyal. There are seven branchiostegals, all arising from the posterior half of the ceratohyal, and all with more or less swollen bases. The seventh is very slender, is not attached directly to the ceratohyal, and reaches just beyond the opercle. The ceratohyal is attached about midway of the length of the glossohyal. The oblique posterior edge of the latter is joined by suture to the first basibranchial. The urohyal is a slender, curving bone swollen both basally and distally. It extends to the level of the second branchial arch.

Branchial Apparatus: (Fig. 6). There are three basibranchials, each separated from the preceding by more than its own length. The first is large, half the size of the glossohyal; the second is very small, slender; the third is again slightly longer, though still slender. In the first two arches hypobranchials are present. The first four ceratobranchials are all moderately slender, the first curved. The fifth is shorter than the rest and is attached to the inner anterior edge of the fourth, except at its dorsal posterior end. It bears several rows of sharp teeth, about
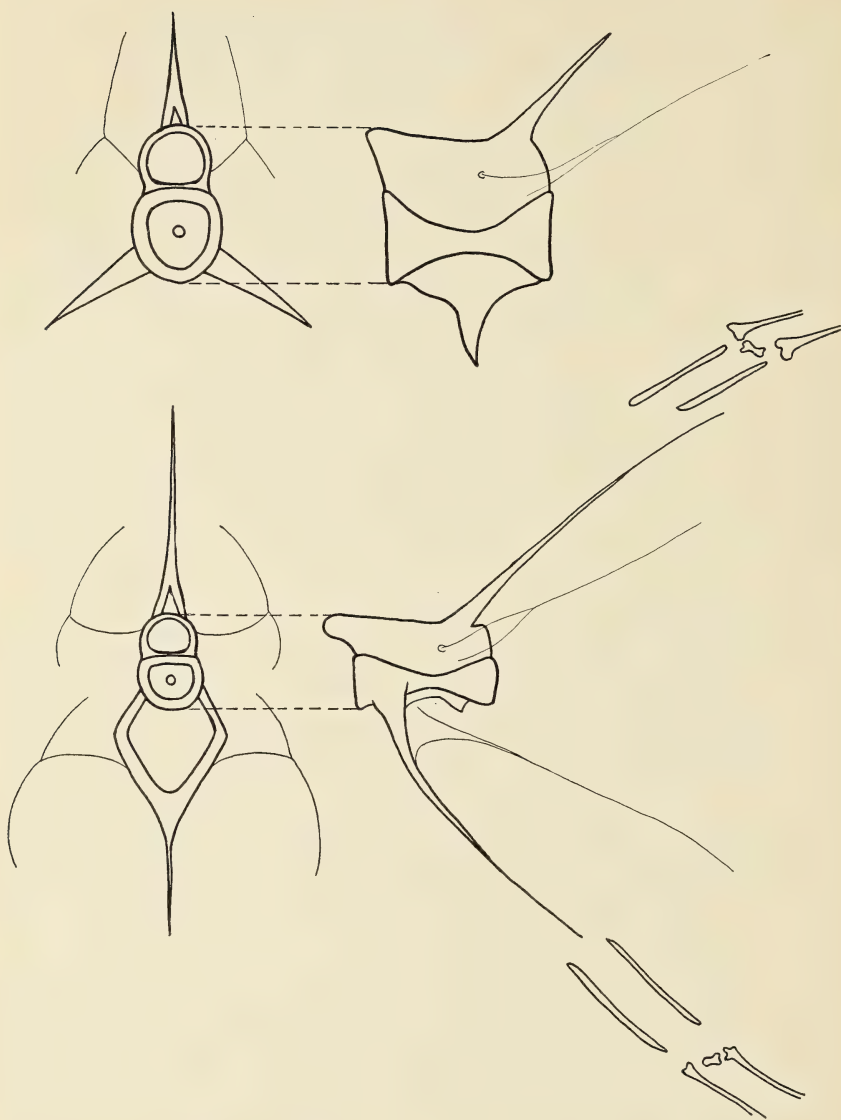
Fig. 7. *Derichthys serpentinus.* Vertebrae of adult female, standard length 268 mm. Upper, 15th vertebra (5th behind pectoral origin) ; lower, 62nd vertebra (6th behind anal origin). (Both x 8.8).

twenty-five in each row. There are four epibranchials of irregular shape. All are small, the fourth much larger than the others. The three pharyngobranchials increase in size posteriorly, teeth being present on the postero-ventral edge of the second and the entire ventral surface of the third. The apparatus has no connection with the vertebral column, and lies low in the branchial cavity.

Pectoral Girdle: (Fig. 5). The supracleithrum is located at the level of the sixth vertebra, half of its length projecting above the centrum. There is no connection with the column. The cleithrum is broad and strong, the center edge straight, the posterior convex. Its upper tip overlaps the lower half of the supracleithrum and is placed close behind it. Coracoids are absent. There are four radials, small but well ossified. The first of the thirteen pectoral rays is slightly separated from the others and has an enlarged base. The fin is far removed from the pectoral girdle.

Vertical Fins and Supports: (Fig. 7). The dorsal fin originates at the level of the 23rd vertebra, the anal at the 56th. The basal thirds of the rays of both fins are ossified as far back as the middle of the anal fin, but posterior to this neither dorsal nor anal shows any bony deposit. Baseosts are well developed, and show ossification more than a dozen rays behind the most posterior finray that shows any stain. The last, unossified baseosts have no definite terminations, each splaying out distally and merging with the adjacent elements, while the bases of the corresponding finrays are indistinguishably merged in the same web of cartilaginous tissue. There are usually two baseosts and rays to each vertebra. Tiny, horizontally placed radials also show faint ossification as far back as the rays, and can be differentiated slightly behind them.

Vertebral Column: (Fig. 7). The slight ossification of the centra and neural arches contrasts with the strongly stained vertebral appendages. Only the last 20 centra of the 130 vertebrae in the large female under discussion show more than traces of stain. The first vertebra is only half the size of the third, the second intermediate. The fourth is very slightly longer than the third, and this size is maintained until the origin of the anal

fin. From here to the tail there is the usual gradual decrease in size to the urostyle.

Throughout the column the neural arches are very large, equalling or exceeding the centra in height. Each arch interlocks with the one before by means of an anterior projection which underlaps the preceding posterior edge. The neural spines of the first nine vertebrae are diverse and specialized. The first is split longitudinally, one half falling immediately behind the other, and joined to it basally by suture. The pair is short, posteriorly directed, and arises at the posterior edge of the arch. The second spine is similar but single. The third, fourth and fifth arise from the anterior half of the arches and are short and forked, one prong behind the other. The sixth, at the level of the pectoral girdle, is represented only by a minute bump. The seventh is a small, posteriorly directed spine in the middle of the arch; the eighth is equal in size, but anteriorly directed; the ninth is low and again forked, arising from the posterior half of the arch. From the tenth to the column's end the spines are well developed, unforked, backwardly directed, and situated at the posterior end of the arch. They are longest in the region of the anterior part of the anal fin, where the length of each is more than twice that of neural arch and centrum combined. Near the caudal base they are relatively much reduced in size, but very strongly ossified. Epineurals, forked basally with only the inner prong attached to the neural arch, are present on every segment except the first and the specialized caudal vertebrae. They are ossified, however, only slightly beyond the middle of the anal fin, though their outlines are traceable almost to the caudal base.

The parapophyses are strong, short spines directed obliquely outward, their broad basal portions arising from the midst of the ventral halves of the centra. There is no trace of ribs. The first three haemal arches lie in front of the anus and lack all trace of haemal spines. Behind the anus, however, they promptly increase in length to equal that of the neural spines, the arches arising from the anterior part of the parapophyses. The first epipleural, an unattached sliver of bone, is found at the thirty-ninth vertebra, slightly behind the middle of the abdominal cavity. The succeeding ones increase in size posteriorly, the
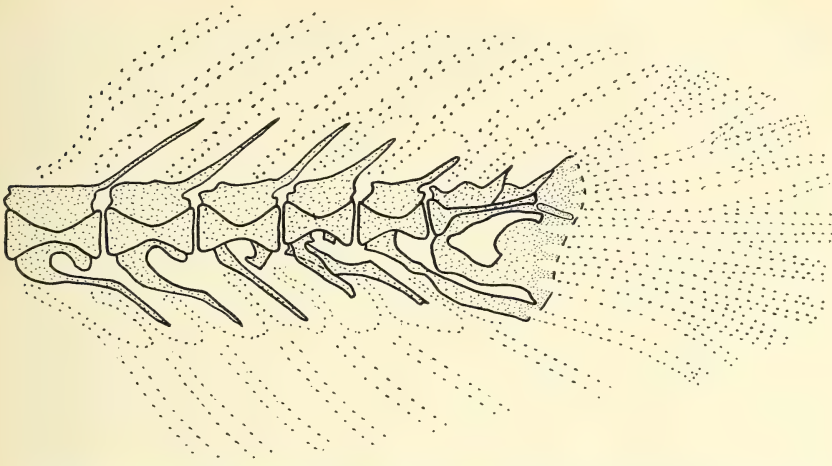
Fig. 8. *Derichthys serpentinus.* End of vertebral column and base of caudal fin in adult female, standard length 268 mm. (x 27.5).

tenth being the first with a forked base. At the origin of the anal (fifty-sixth vertebra) they attain their maximum size, and from here on correspond to the epineurals, ossification dying out similarly behind mid-anal. Their outlines, however, are traceable, like those of the epineurals, almost as far back as the specialized caudal vertebrae.

End of Vertebral Column and Caudal Fin: (Fig. 8). Two unusual characteristics of the tail structure of this eel are, first, the almost complete absence of osseous tissue, and second, the persistance of the neural arch and spines throughout the entire dorsal length of the urostyle. The only caudal specialization of centra, neural arches and spines is a gradual reduction in size. There is a radical change posteriorly in the haemal arches and spines. On the 125th or fifth pre-urostyle vertebra, the haemal arch base, in typical fashion, extends almost the full length of the centrum, narrowing in the center to form a well-marked bay with the proximal portion of the spine. Posteriorly the backward extension of the arch decreases and finally on the last vertebra disappears. There is no open arch on the penultimate vertebra, the two lateral elements being quite unjoined and very unlike.

The urostyle extends back as a straight rod for a length

greater than that of the preceding vertebra. On its dorsal sur-
face it supports two well developed neural arches. At its end,
and bounded above by the last neural spine, is the first hypural,
supporting five caudal rays. Below is a larger cartilaginous
area with an extensive central foramen, irregular but giving no
definite hint marking a division into separate elements. So we
must indicate the whole of this area as the second hypural, sup-
porting the succeeding four caudal rays. The haemal spine of
the last vertebra is extended backward into the long, slender
third hypural from which arises the last and tenth caudal ray.

Pore System: The pores of the snout are supported by tiny
bony tubules connected with unossified channels, while the lower
jaw has a perforation corresponding to each pore in that area.
Connection from both regions is made with the lateral line in
the usual manner, via the post-temporal canal and the pre-
opercle. The more posterior pores of the head and those of the
neck and lateral line have no bony support.
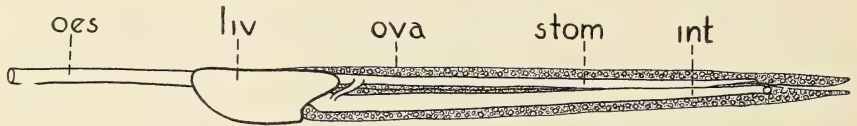
Fig. 9. *Derichthys serpentinus.* Digestive and reproductive systems in adult female,
standard length 268 mm. (x 1.2).

DIGESTIVE SYSTEM: (Fig. 9). None of the digestive organs
is pigmented, although the lining of the coelom has a thin scat-
tering of chromatophores. The oesophagus opens directly into
the stomach, slightly in front of the posterior tip of the liver.
The stomach, very slender when not distended by food, barely
reaches the anus, lying to the left of the equally slender intestine.
The pyloric canal connecting the two organs has no caeca, extends
obliquely forward. The liver is single-lobed, the left half the
longer, and lies as usual ventral to the oesophagus and the oval
gall bladder. The bile duct is short, entering the swollen pyloric
region of the intestine at its most anterior point. The pan-
creatic tissue is practically indistinguishable from that of the
liver.

REPRODUCTIVE SYSTEM: (Fig. 9). The ovaries originate
at the level of about the middle of the liver and extend posteri-

orly against the dorsal wall of the coelom to a distance behind the anus equal to two-thirds the length of the liver. The left ovary is always slightly longer than the right. In the only specimen near breeding condition, there is a total of about 4,100 eggs, each measuring about .75 mm. in diameter. In addition there is at least an equal number of very minute eggs, each at most .14 mm. across. This circumstance makes it appear very probable that these deep-sea eels breed more than once.

DEVELOPMENT

MATERIAL: Adolescents and transitional adolescents predominate in the Bermuda collections; larvae and post-larvae are absent:

Adolescents: 55 to 90 mm.—8 specimens (Figs. 3A, 4A).

Transitional Adolescents: 98 to 198 mm.—9 specimens (Figs. 3B, 4B).

Adults (Females): 255, 268 mm.—2 specimens (Figs. 3C, 4C).

KEY TO THE GROWTH STAGES:

A. Body more or less flattened, semi-leptocephaloid; pigment lacking .... *Adolescent*
AA. Body of adult form; pigment present.
    B. Gonads very inconspicuous, pigment incomplete or pale; skeleton not fully ossified
                                                       Transitional Adolescent
    BB. Gonads well developed; pigmentation complete; skeleton fully ossified .... *Adult*

CHANGES OCCURRING DURING GROWTH: The smallest specimens (55 to 90 mm.) are typical eel adolescents, having no trace of larval teeth, the fins complete and in practically their final positions, and bodies, though somewhat flattened, well beyond the leptocephalid stage and almost as slender, relatively, as in the adults. The following differences are apparent, however, when compared with transitional adolescents and adults: Pigment is entirely lacking except for a line of minute chromatophores—doubtless remains of larval pigment—extending from

the anus to the caudal in the mid-line; this is lacking in larger adolescents. The body is otherwise perfectly white and opaque, except for rosy iridescence on the head, opercles, and, irregularly, along the sides; the abdomen is usually more brightly iridescent, with blue and violet tints predominating. In the largest adolescents there is a patch of pigment on the crown beneath the epidermis. The head is slightly larger than in older specimens; eye and snout, however, are of adult proportions. The teeth are feeble, but the full number is present, with the exception of the anterior cluster of vomerine teeth. The anal fin may originate very slightly in advance of the middle of the body, instead of at or behind this point. The finrays are more easily countable at this stage than later on, as the membranes are still thin. All of the pores, both cephalic and lateral line, are present, fully formed on the head but rudimentary along the lateral line. The striations are also developed, but are inconspicuous. The adolescent shows a moderate amount of ossification, the jaws and teeth being very strongly stained, and the jaw supports, hyoid and branchial arches, and pectoral girdle only slightly less firmly ossified. The brain-case, opercles, basal pectoral rays, vertebral column and external cephalic canal bones show moderate amounts of bony deposition in the larger adolescents, but in no specimen of this stage do the vertical fins, their baseosts or their radials show any trace of stain. In contrast to corresponding bones in the adult, the seventh branchiostegal ray is longest and strongest instead of shortest and weakest, while the urohyal is perfectly straight, instead of deeply curved. The digestive system differs from that of the adult only in the slightly shorter stomach, which in the smaller specimens ends a full snout's length in front of the anus. The gonads are rudimentary.

In the transitional adolescents (98 to 198 mm.) the entire skin is frequently tinged with warm pink, and true dark pigment first appears, spreading from the top of the neck backward, downward and forward. Specimens measuring 160 mm. and over are completely covered with pigment, but these fish are slightly paler than adults. There are small reductions in the length of the head and in the depth. The skeleton gradually becomes more strongly ossified. The digestive system does not

differ from that of the adult; the gonads are distinguishable, but very slightly developed.

The two fully adult specimens of the collection differ in proportions very little from the younger fish, as may be seen from the following summary of measurements made on all the specimens in the collection:

Growth Stage	Length Depth	Length Head	Length Head minus Neck	Head Eye	Head Snout	Length Snout to Dorsal	Length Snout to Anal
Adolescent (55 to 90 mm.)	18— 25.7	6.5— 7	10— 11.8	8.2— 10.2	5— 6.4	3.9— 4.3	2— 2.3
Transitional Adolescent (98 to 198 mm.)	16.5— 25	6.5— 7.7	10.4— 12.5	7.1— 8.8	5.4— 6.7	3.7— 4.2	1.8— 2
Adult (255, 268 mm.)	19— 22.5	8.1— 8.4	14.5— 15	8.2— 8.8	5— 6.2	3.8— 4	1.8

ECOLOGY

SEASONAL DISTRIBUTION: Eleven of the eighteen specimens were taken in September, four in June, three in August.

VERTICAL DISTRIBUTION: *Derichthys* occurred only between 500 and 1,000 fathoms, at an average depth of 755 fathoms. No correlation is seen between season and depth.

ABUNDANCE: *Derichthys* is rare among the deep-sea fish of Bermuda, only one occurring in every 55 nets drawn between 500 and 1,000 fathoms, the Bermuda limits of its vertical distribution.

SOCIABILITY: Not more than a single specimen was ever taken in the same net.

FOOD: In five stomachs were traces of crustaceans, usually unquestionably shrimps and recognizable in one case as *Sergestes* sp. The latter measured 64 mm. in length, and had been swallowed tail first by a 132 mm. *Derichthys*. Unrecognizable remains of food were usually present in the intestines.

ENEMIES: A 198 mm. *Derichthys* had a number of parasitic worms embedded in the stomach wall.

VIABILITY: No *Derichthys* has ever been taken alive.

STUDY MATERIAL

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of each specimen of *Derichthys serpentinus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in ZOOLOGICA, Vol. XVI, No. 1, p. 5. "Trans. Adol." stands for "Transitional Adolescent."

No. 10,297; Net 148; 700 F.; June 1, 1929; 85 mm.; Adolescent.
No. 10,450; Net 167; 800 F.; June 14, 1929; 178 mm.; Trans. Adol.
No. 10,534; Net 177; 600 F.; June 17, 1929; 80 mm.; Adolescent.
No. 10,953; Net 219; 600 F.; June 25, 1929; 104 mm.; Trans. Adol.
No. 13,518; Net 475; 800 F.; Sept. 13, 1929; 159 mm.; Trans. Adol.
No. 13,712; Net 495; 800 F.; Sept. 23, 1929; 102 mm.; Trans. Adol.
No. 17,501; Net 822; 600 F.; Sept. 1, 1930; 58 mm.; Adolescent.
No. 17,778; Net 837; 600 F.; Sept. 3, 1930; 55 mm.; Adolescent.
No. 18,611; Net 890; 1,000 F.; Sept. 15, 1930; 62 mm.; Adolescent.
No. 19,281; Net 941; 1,000 F.; Sept. 24, 1930; 198 mm.; Trans. Adol.
No. 19,451; Net 953; 1,000 F.; Sept. 26, 1930; 133 mm.; Trans. Adol.
No. 19,547; Net 964; 600 F.; Sept. 29, 1930; 116 mm.; Trans. Adol.
No. 21,884; Net 1,121; 500 F.; Aug. 3, 1931; 98 mm.; Trans. Adol.
No. 22,680; Net 1,209; 1,000 F.; Aug. 20, 1931; 268 mm.; Adult.
No. 22,975; Net 1,244; 800 F.; Aug. 31, 1931; 255 mm.; Adult.
No. 23,110; Net 1,261; 600 F.; Sept. 4, 1931; 90 mm.; Adolescent.
No. 23,230; Net 1,278; 700 F.; Sept. 9, 1931; 79 mm.; Adolescent
No. 23,611; Net 1,317; 900 F.; Sept. 17, 1931; 104 mm.; Trans. Adol.

SYNONYMY AND REFERENCES

Derichthys serpentinus:

Gill, 1887, p. 433. (1 specimen; 8 in.; 1,022 fathoms; 39° 44′ 30″ N. Lat., 71° 04′ W. Long.; off New Jersey; *type specimen*).

Goode and Bean, 1895, p. 161, fig. 169. (Supplementary type description).

Parr, 1934, p. 32, fig. 10. (1 specimen; length not given; 1,050-1,100 metres; 25° 39′ N. Lat., 77° 18′ W. Long.; Bahamas. Discussion of synonymy of *D. iselini* with *D. serpentinus*.)

Derichthys iselini:

Borodin, 1929, p. 110. (1 specimen; 165 mm.; 1,000-0 fathoms; 50° 41′ N. Lat., 27° 17′ W. Long.; Middle North Atlantic, three-fifths of distance between Newfoundland and Scilly Isles).

Borodin, 1931, p. 75, pl. 3, figs. 4-6. (Supplementary type description).

Grammatocephalus kempi:
Norman, 1930, p. 339, fig. 34. (1 specimen; 160 mm.; 850-950 metres; 33° 50′ to 34° 13′ S. Lat., 16° 04′ to 15° 49′ E. Long.; off Cape Town).

Derichthys kempi:
Trewavas, 1932, p. 641, text-fig. 2 (Supplementary description of the type specimen of *Grammatocephalus kempi* and remarks on the relationships of the family.)
A bibliography will be found on p. 50 of the present volume.

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

FAMILY NESSORHAMPHIDAE[1]

WILLIAM BEEBE

(Figs. 10-22 incl.)

CONTENTS

INTRODUCTION

All of the remarks in the Introduction to the preceding paper on the family Derichthyidae apply also to the present account. They will be found on p. 1 of this volume.

FAMILY NESSORHAMPHIDAE Schmidt 1931

Body anguilliform, slender, more or less cylindrical anteriorly but with caudal region rather compressed; anus behind middle of length; scales absent; lateral line with distinct pores; snout very long, flattened, spatulate, projecting far beyond the narrow lower jaw, its tip enlarged and holding the olfactory sac; anterior nostril terminal, posterior slightly behind it, dorso-

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[1] Contribution No. 479, Department of Tropical Research, New York Zoological Society.

lateral; neither nostril tubular; teeth conical, cardiform, in bands on both jaws, on vomer proper and on intermaxillary extension of vomer; tongue scarcely or not at all free anteriorly; branchial apertures widely separated slits of moderate size, inserted immediately in front of the well developed pectorals; dorsal beginning behind head, far in advance of anal; dorsal and anal confluent with caudal, which is short but well developed. One genus.

Genus **Nessorhamphus** Schmidt 1930

With the characteristics of the family. One species described; the Indo-Pacific forms may, however, prove to be distinct. General range: The warmer and saltier parts of the Atlantic, Indian and Pacific Oceans.

Nessorhamphus ingolfianus Schmidt 1930 (Schmidt 1912)

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC
EXPEDITIONS

Twenty-one specimens; April to September, 1929 to 1931; 400 to 1,000 fathoms; from a cylinder of water eight miles in diameter (five to thirteen miles south of Nonsuch Island, Ber-
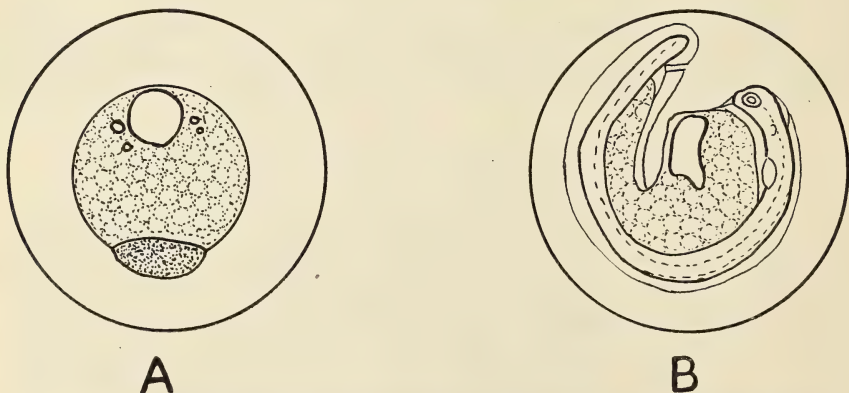
Fig. 10. Stages in the development of *Nessorhamphus ingolfianus.* A, egg, early stage; B, egg, late stage. (Both x about 16; after Táning, in Schmidt 1930).
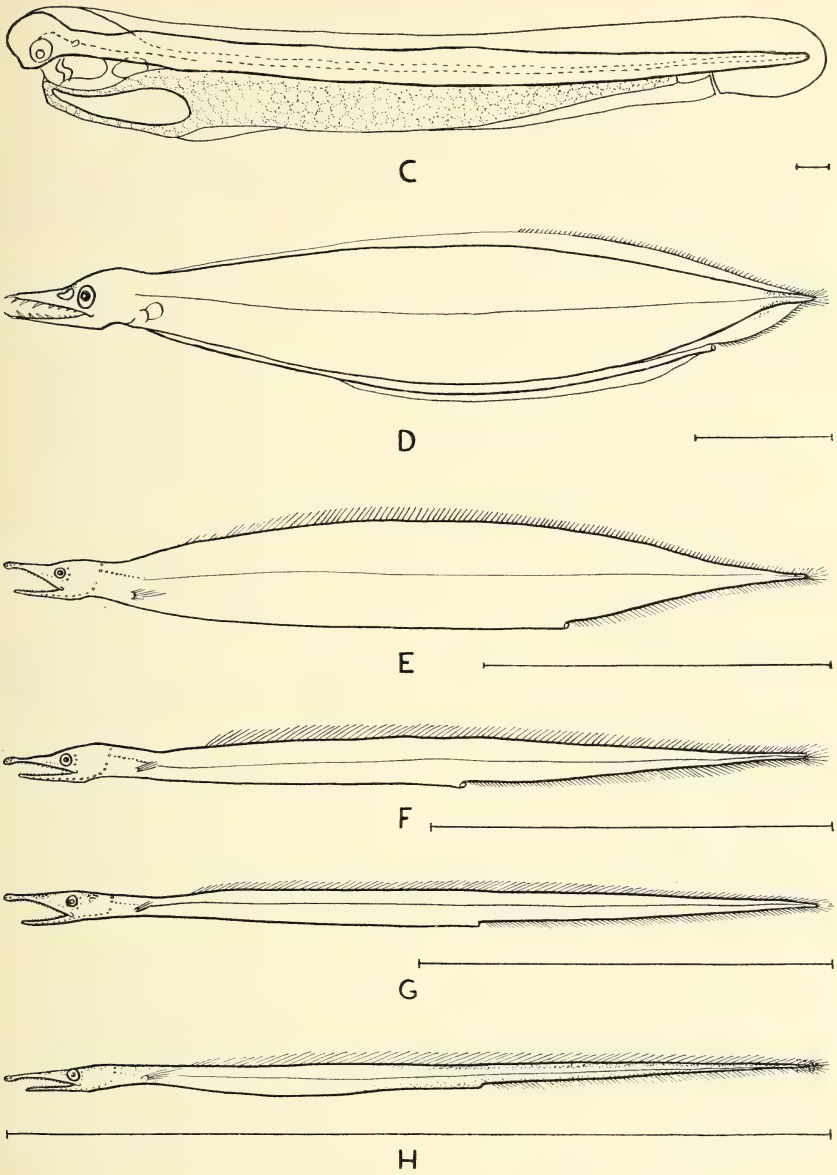
Fig. 10 (continued). Stages in the development of *Nessorhamphus ingolfianus*. C, Pre-larva, 3 to 5 hours old; D, larva, 28 mm.; E, post-larva, 69 mm.; F, adolescent, 81 mm.; G, transitional adolescent, 92 mm.; H, transitional adolescent, 166 mm. The relative size of the specimens is indicated by the straight lines. (C, after Tåning, in Schmidt 1930; D-H incl., from specimens taken by the Bermuda Oceanographic Expeditions).

muda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 26 to 166 mm.

SPECIMENS PREVIOUSLY RECORDED

Many thousands, the majority young and immature forms, were taken by the Danish research vessels within the past twenty years. Dr. Schmidt only found time, however, to publish brief preliminary descriptions. The eggs and smaller larvae were found to be pelagic, and the older forms bathypelagic. Range: Warmer parts of North Atlantic. Length: Egg to 248.5 mm., the type specimen.

DESCRIPTION OF ADULT

COLOR: Brownish, sides with bluish tinge.

PROPORTIONS: Depth in length 30 (small specimens) to 25 (large specimens); head in length 6 to 7.2; eye in head about 10.6; snout in head about 2.4; snout to dorsal origin in length 4.6 to 4.8; snout to anal origin in length about 1.8.

TEETH: Conical, cardiform; maxillary and mandible with narrow bands formed of from one to four irregular, broken rows of teeth, the band being single-rowed only in the extreme posterior part of the jaw, a maximum of 60 to 90 teeth in each row; a patch of similar teeth, about 35 or 40, on the intermaxillary extension of the vomer, and, posterior to these after an interval, an elongate patch on the vomer proper; the latter series are the last to develop; in the large, type specimen they number more than 100 according to Schmidt's figure (1930, pl. IV).

FINS: Pectoral rays 13, at least six times as long as eye in perfect examples, but usually broken; dorsal rays 276 to 291, the rays longest on the caudal peduncle, opposite the middle section of the anal fin; dorsal origin less than a snout's length behind pectoral base; anal rays 160 to 175, the rays much shorter than those of the dorsal; caudal fin truncated, continuous with dorsal and anal.

PORES AND LATERAL LINE: Head with conspicuous mucous pores; fine parallel ridges near tip of snout and before and behind eye. About 132 pores in lateral line, which commences

above the mid-line, but coincides with it from about the middle of the length posteriorly.

BRANCHIOSTEGALS: 6 to 7.

MYOMERES AND VERTEBRAE: 150 to 159 (72 to 73 pre-anal).

OSTEOLOGY; DIGESTIVE SYSTEM: Descriptions of these as they occur in slightly immature specimens commence on p. 37.

DEVELOPMENT

MATERIAL: The Bermuda collection consists of all stages from moderately young larvae to large transitional adolescents. Eggs and pre-larvae were described in Dr. Schmidt's paper by Dr. Tåning (1930, p. 275) and his description will be quoted below, so that the various growth stages of this eel will be completely summarized in the present paper. We do not know, however, whether the 248.5 mm. type specimen was fully mature. The Bermuda material is distributed as follows:

Larvae: 26, 28 mm.—2 specimens (Figs. 10D, 11A).

Post-larvae: 68 to 72 mm.—5 specimens (Figs. 10E, 11B).

Adolescents: 78, 81 mm.—2 specimens (Figs. 10F, 11C).

Transitional Adolescents: 80 to 166 mm.—12 specimens (Figs. 10G, 10H, 11D, 11E).

KEY TO THE GROWTH STAGES:

A. Body leptocephaloid (depth in length not more than 22; usually very much less) ; no general pigment on body.

    B.   Larval teeth present; snout scarcely or not at all prolonged beyond mandible; anal origin far back, at 118th to 121st myomere ....*Larva*

    BB. Larval teeth absent; snout showing characteristic shape and prolongation.

        C.   Anal origin not in final position, but located between about 116th and 76th myomeres; depth in length 7.4 to 9.6..*Post-larva*

        CC. Anal origin in final position, between 74th and 72nd myomeres; depth in length 18 to 20......*Adolescent*

AA. Body anguilliform (depth in length 29 or 30) ; general pigment appearing on body....................*Transitional Adolescent*
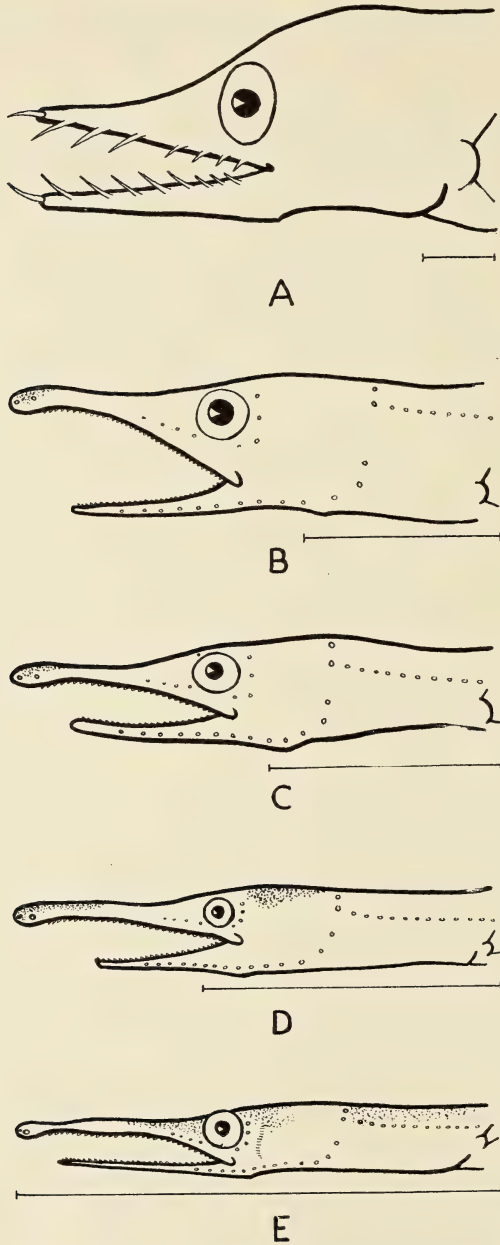
Fig. 11. Heads of *Nessorhamphus ingolfianus*. A, larva, standard length 28 mm.; B, post-larva, standard length 69 mm.; C, adolescent, standard length 81 mm.; D, transitional adolescent, standard length 92 mm.; E, transitional adolescent, standard length 166 mm. The relative size of the specimens is indicated by the straight lines.

(In fully pigmented, large specimens the body evidently, as is usual, becomes secondarily deeper, the depth being contained according to the type description only about twenty-five times in the length.)

EGG AND PRE-LARVA (From Tåning's description, Schmidt, 1930, p. 275) : "The egg is a typical, highly transparent, floating muraenoid-egg with a wide perivitelline space; vitellus nearly colourless with a light tinge of yellow. The membrane of the egg is for a deep-sea muraenoid-egg rather thick. Vitellus vesicular with one large oil globule, which at a very early stage in development—prior to advanced cleavage of the germinal disc—is a cluster of small oil-globules. The size of the egg is: Diameter 2.4-2.70 mm., vitellus 1.20-1.35 mm. and oil globule 0.42-0.48 mm. [see Figs. 10A, B]. The pre-larva, which leaves the egg at an early stage (abt. 7 mm.) has the oil globule situated anteriorly in the yolk-sack; in this stage it has abt. 84 abdominal segments. Pigment not present.

"In the Sargasso Sea the eggs were found in large quantities, especially numerous about May.

"The eggs resemble to a high degree those of the muraenoid fish to which *Leptocephalus anguilloides* Schmidt 1916 belongs. The eggs of this species are however smaller (less than 2.40 mm.) and have a larger vitellus (1.50-1.65 mm.), with accordingly a smaller peri-vitelline space."

The following résumé of the changes occurring during growth is based only upon the Bermuda material; where comparison was possible from the short description of the larva and from the series of photographs, the present specimens checked perfectly with corresponding ones in the Danish collection. A table of proportions will be found on p. 47.

LARVA: The two larvae, 26 and 28 mm. in length, are typical leptocephali. Pigment is present only on the tail, in an irregular series of tiny chromatophores in and near the mid-line, and sparsely along the posterior parts of the fin bases. The larva is moderately deep; the tail tip rather attenuated; the head fairly small; eyes vertically elongate, larger than in succeeding stages; snout long, but no longer than the mandible; the latter already shows its characteristic narrowness. The nostrils are located
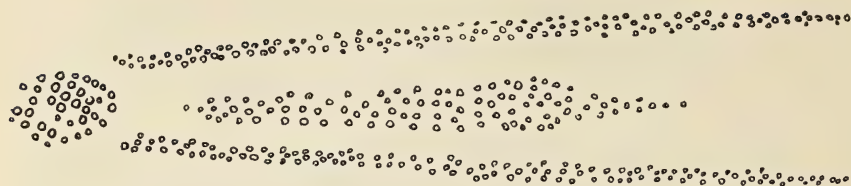
Fig. 12. *Nessorhamphus ingolfianus*. Dentition of upper jaw in transitional adolescent, standard length 142 mm. (x 11).

just in front of the eye. The larval fangs number eight pairs in the upper jaw and nine in the lower; in the maxillary the last four teeth on each side are much smaller than the anterior ones; in the mandible the same is true of the last three pairs. The pectoral has the usual fleshy base, fringed with raylets. The bases of both dorsal and anal fins are elevated, the rays not yet well enough developed to be counted with accuracy. The gut ends and the anal commences far back, on the posterior tenth of the body, lying between the 118th and 121st myomeres. The dorsal is traceable almost as far forward as the middle of the length. The caudal rays are well developed. Cephalic and lateral pores are invisible. The gut, suspended below the body wall, is entirely unpigmented; it is a simple tube with the anlage of the liver and other organs barely appearing.

Osteology: (Figs. 13, 14, 15). These larvae of course show no trace of ossification, but the principal cartilaginous elements of the head are traceable even in the unsectioned, preserved specimens, and are full of interest. The chief difference between the heads of larva and adult lies in the proportions of the chondro-cranium: the nostrils, as noted above, are situated not terminally, but close in front of the orbits. The frontals, fused even at this early stage, do not enter into either the roof of the snout nor that of the skull proper, being confined to the interorbital region. The future growth of the snout tissue will hence take place chiefly in the now narrow area between nostril and orbit, through the anterior projection of the frontals and posterior growth of the ethmoid, so that eventually the nostrils will be thrust far forward. As in the mature fish, the parietals are large and well marked. A relatively large supraoccipital can be traced. The otic region is not yet differentiated into epiotics and pterotics, but occupies the entire posterior and lateral por-

tions of the brain-case. Viewed from above, the two epiotic regions diverge posteriorly from the supraoccipital into large wing-like processes.

All of the elements of the palato-pterygoid, jaw and opercular apparati are discernible and differ from the corresponding bones of the adult only in their typically immature lack of shapeliness and their general tendency to robust stockiness. The opercular apparatus in particular shows generalized characters, the opercle being fan-shaped, bounded ventrally and posteriorly by the broad subopercle. As in generalized fish also, the entire apparatus does not extend behind the vertical from the posterior margin of the brain-case, while in the adult it projects much farther. In the larva, too, a well defined gill opening appears in its normal place, beneath the gill flap formed by opercle and subopercle. The hyoid apparatus likewise has the elements of the adult, save that no branchiostegal rays are visible. The ceratohyal arises relatively farther back along the glossohyal.

The branchial apparatus has the rudiments of the two hypobranchials, five ceratobranchials and four epibranchials of the adult, but the pharyngobranchial elements are only questionably identifiable. The generalized shape of the gill arches is apparent, all of them being vertical and consecutive, and all are crowded beneath the broad main column of the hyomandibular and the region immediately behind—far forward of their subsequent location in the "neck" of the metamorphosed eel.

Post-Larva: The post-larva is slightly more slender than the larva, larval teeth are missing and permanent teeth appearing, the snout assumes its characteristic configuration, with the nostrils approaching ever closer to their final position, and— an invariable character of this stage among the Apodes—the anus and anal fin are in the act of moving forward, and lie somewhere between about the 116th and the 76th myomeres. The rays are easily countable at this stage, but are relatively short, with their bases still elevated. The same applies to the dorsal rays, which have also migrated, so that before the end of the post-larval stage the fin originates in its final position back of the head. The cephalic pores are now discernible. The gut is almost completely enclosed within the body cavity.
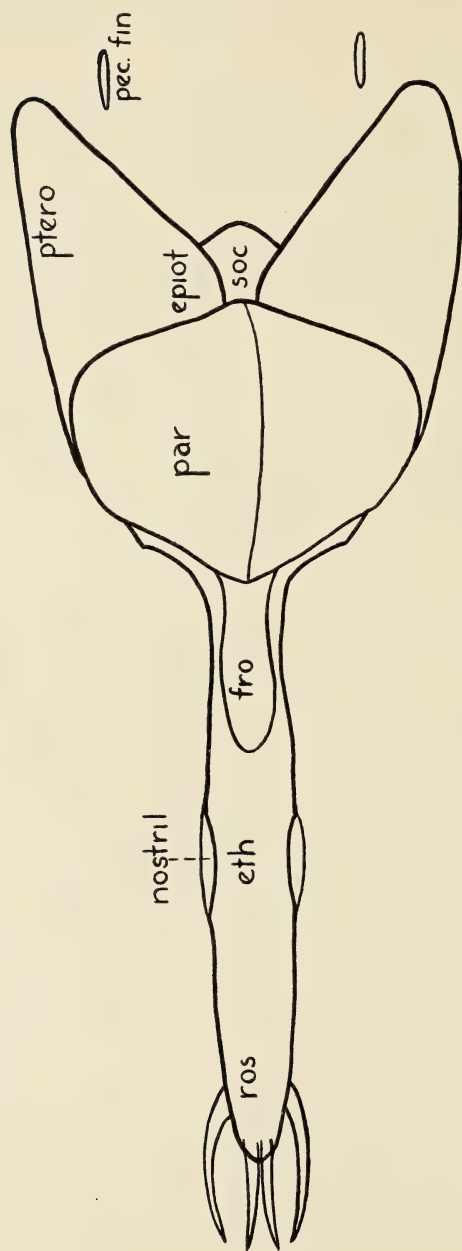
Fig. 13. *Nessorhamphus ingolfianus.* Skull of larva, standard length 28 mm.; dorsal view. (x 42).

Fig. 14. *Nessorhamphus ingolfianus.* Skull of larva, standard length 28 mm.; lateral view. (x 42).
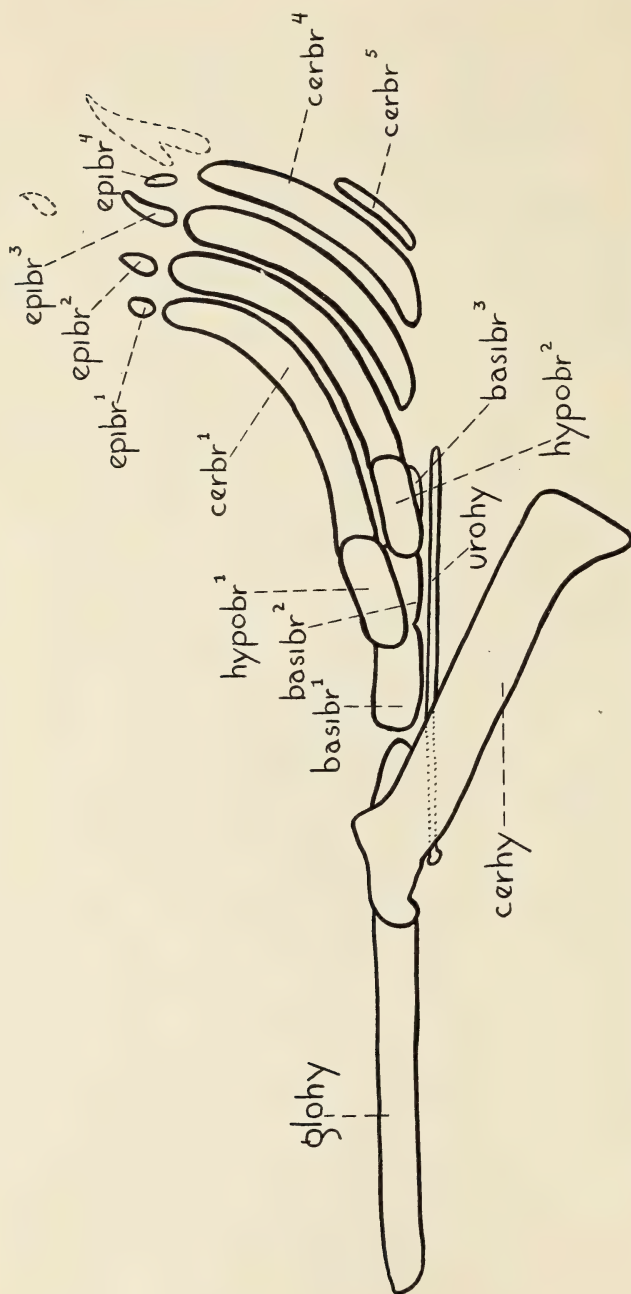
Fig. 15. *Nessorhamphus ingolfianus.* Hyoid and branchial apparatus of larva, standard length 28 mm. (x 100).

ADOLESCENT: In the adolescent stage the fins are in the same relative positions as in the transitional adolescent and adult; the body is less than half as deep as in preceding stages and a distinct thickening is apparent, although the general appearance is still distinctly leptocephaloid. All traces of larval pigment have disappeared, and permanent coloration is appearing on the tip of the snout, and, less densely, along its top and the crown of the head, beneath the outer epidermis. As Schmidt has remarked, in contrast to what is known in the case of many other eels, a distinct increase in length is apparent throughout metamorphosis. In his series, metamorphosing stages (corresponding to our post-larvae and adolescents) have a length of from 62 to 85 mm.; the youngest post-larva and most advanced adolescent in the Bermuda material measure respectively 70 and 81 mm.; a shrinkage of two or three millimetres at most seems to be all that takes place at any point in the development.

TRANSITIONAL ADOLESCENTS: The transitional adolescents, the "glass eels" of Schmidt, have the rounded, slender form of grown eels, but in this species pigment appears very gradually and late, and the full number of teeth—especially along the vomer proper—is only gradually attained. The largest Bermuda specimen, measuring 166 mm., appears almost white to the unaided eye, although it has all other adult characters with the exception of complete vomerine dentition (Fig. 12) and mature reproductive organs. Examination shows a dark spot on the tip of the snout, and fine chromatophores scattered over the head, jaws, cardiac and abdominal regions, the base of the anal fin, the base of the posterior half of the dorsal fin, and the end of the caudal peduncle; there is a fairly conspicuous, vertical band of dark brown across the middle of the caudal rays.

Osteology: The skeleton of a specimen of 142 mm. has been studied in detail, and compared both with younger examples of the Bermuda collection and with the 128 mm. specimen described and figured by Trewavas (1932). The latter differs from the present specimens chiefly in smaller epiotics.

In the youngest of the transitional adolescents examined, a specimen of 87 mm., the entire skeleton with the exception of the vertical finrays showed faint ossification, strongest on the jaws and weakest along the vertebral column. In the 148 mm.

example, ossification is much stronger throughout, with the exception of the sides and base of the brain-case, the coracoids and the radials, all of which show very faint stain, while the anterior dorsal finrays and all of the anal rays are entirely unossified.

Skull: (Figs. 16, 17). The most interesting characteristic of this region is the manner of the prolongation of the skull. Unlike the snouts of the comparable Nemichthyds, the lengthening has been brought about chiefly by the elongation of the frontals. The brain-case is perfectly oval. The epiotics occupy the posterior fourth of its dorsal surface. Anterior to these are the oblong parietals, twice as long as the epiotics in our specimens. The tiny supraoccipital is enclosed completely by the epiotics and parietals. The elongate pterotics form the major element of the sides of the brain-case. A sensory canal runs its full length, overlapping the frontal. The frontals are completely fused except anteriorly. About a third of their length is postorbital, forming the anterior fourth of the brain-case. At their posterior border their combined width is about equal to the length of this postorbital section. They narrow gradually, and are extremely narrow above the eyes, then broaden slightly to split at their junction with the ethmoid, the forked ends projecting into that bone laterally as far as the middle of the snout. In the Bermuda specimens there is no ossification of the spindle-shaped ethmoid anterior to the nostrils, although Trewavas shows a strong, compact ethmovomer.

Palato-pterygoid Arcade: (Fig. 17). The hyomandibular in this species is an irregular quadrilateral with excavated sides. Its upper anterior angle articulates with the small, crescentic sphenotic arising from the pterotic, beneath the postero-lateral corner of the frontal. A broad wedge of the hyomandibular extends backward parallel with the pterotic, slightly beyond the edge of the brain-case, its apex forming the second angle of the quadrilateral. Diagonally opposite the sphenotic articulation a shorter arm joins the opercle. The fourth angle is formed by the typically hyomandibular arm which extends antero-ventrally to join the quadrate. The latter, connecting with the angular, is perfectly horizontal. The symplectic is large, equal to the quadrate in length and thickness; it lies above the quadrate and posteriorly overlaps the hyomandibular. The slender, rod-like pte-

rygoid extends between the posterior part of the quadrate and the posterior portion of the vomer. There is no trace of a separate palatine. The vomer lies against the ventral surface of the ethmoid, broadening anteriorly and dipping ventrally to floor the bulbous snout tip. Between vomer and brain-case extends the strong and slender parasphenoid.

Jaw Apparatus: (Fig. 17). The slender maxillary originates at the posterior boundary of the swollen snout tip, ending close to the vertical from the posterior margin of the eye. Posteriorly it has a strong, downward curve. The strong dentary is notably shorter than the snout, its tip being even with that of the maxillary. It is slender anteriorly, with a slight expansion at the symphysis. Posteriorly it broadens considerably. The articular is of moderate size and clearly defined, although the angular boundaries are indeterminable.

Opercular Bones: (Fig. 17). All of the opercular bones are reduced and practically non-functional, as is usual in eels, lying far forward of the gill opening. The preopercle, lying distinct from and below the quadrate and hyomandibular, is slender and tubular, forming part of the mucous canal system. Below this, and extending beyond its posterior end, is the small interoperculum, and behind this a wiry suboperculum, lying immediately beneath the trapezoidal, oblong opercle, and curling up around its posterior end.

Mucous Canal Bones: (Fig. 18) In this system the pterotic canal dorsally and the preopercular and mandible ventrally, serve as correlative units. Near the posterior margin of the brain-case a small superficial tube links the preopercle with the pterotic and lateral line. Similar superficial bones, only partially ossified, surround the eye and extend dorsally and ventrally throughout the length of the snout, extending to its extreme tip, where a pair of small, terminal tubules lies between the ends of the upper and lower sets.

Hyoid Arch: (Fig. 19). The glossohyal is long, and ossified as far forward as the broadest portion of the dentary; posteriorly it almost reaches the vertical from the attachment of the opercle. The ceratohyals arise from the middle of this ossified portion. There is a hint in one of the Bermuda specimens of a division into basihyals and ceratohyals, the lines of demarcation
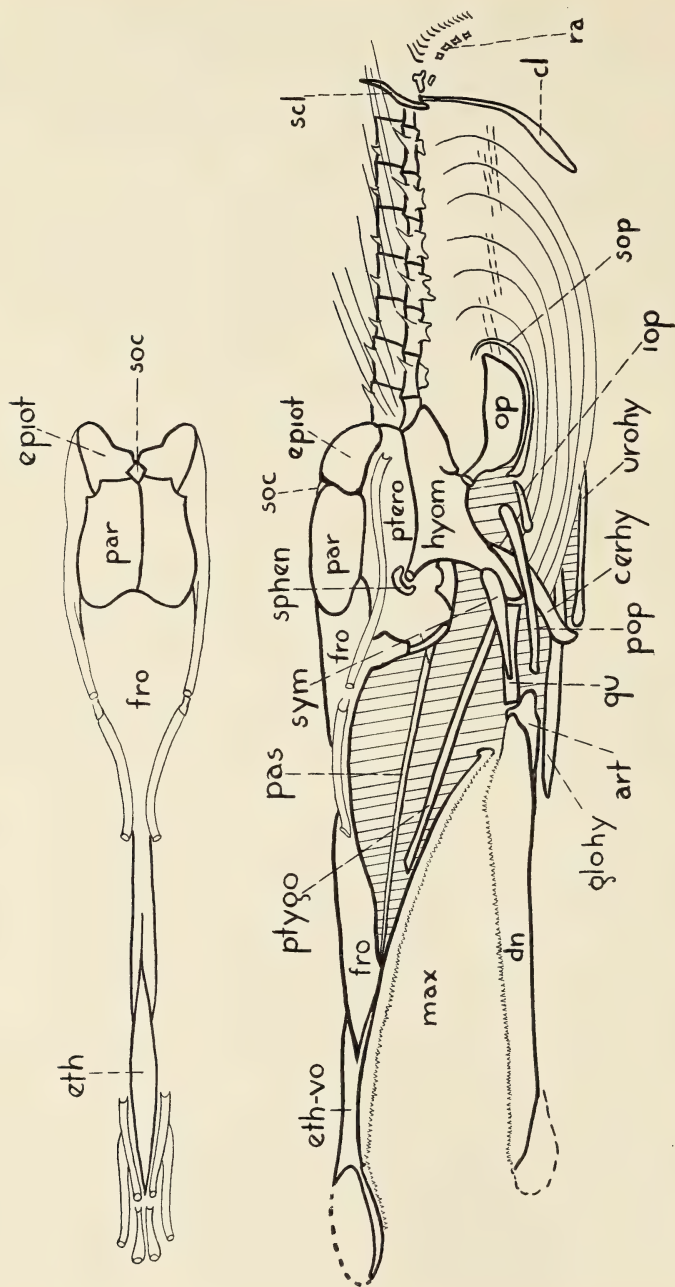
Fig. 16 (Upper). *Nessorhamphus ingolfianus*. Skull of transitional adolescent, standard length 142 mm.; dorsal view. (x 6.8).

Fig. 17 (Lower). *Nessorhamphus ingolfianus*. Bones of head, pectoral girdle and anterior part of vertebral column, in transitional adolescent, standard length 142 mm.; lateral view. (x 6.8).
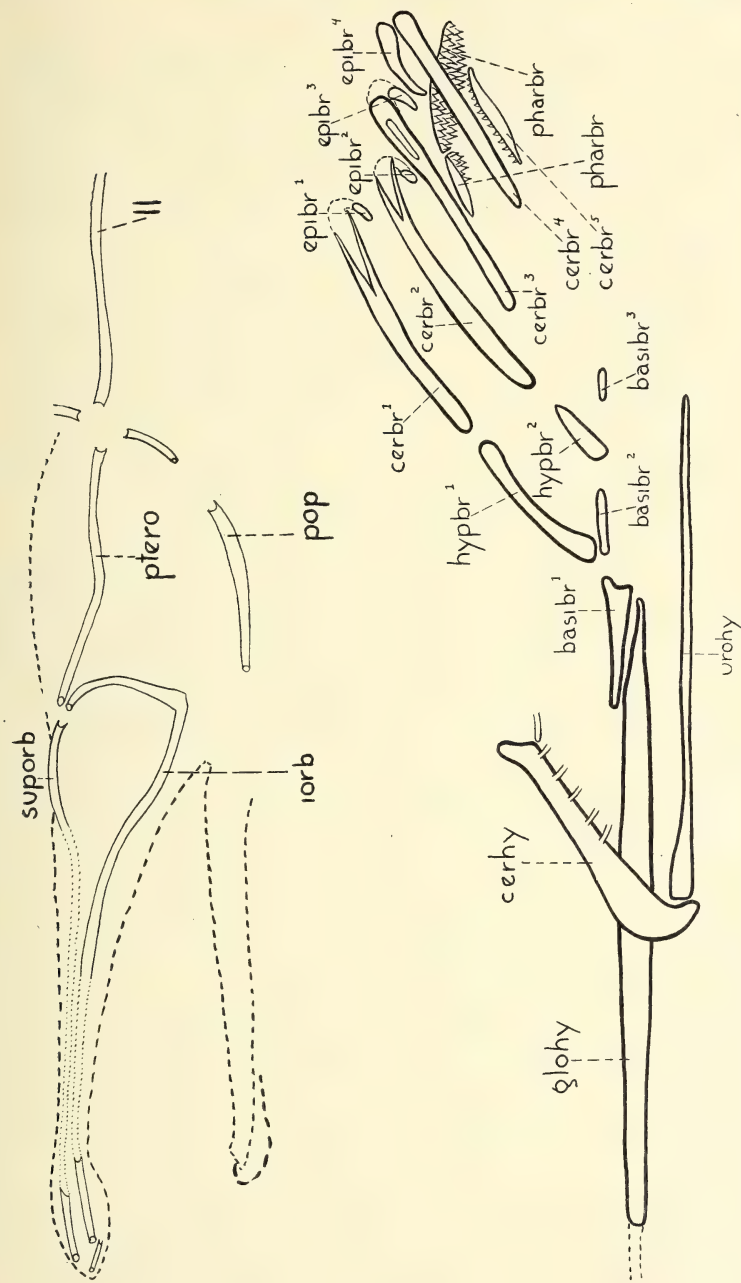
Fig. 18 (Upper). *Nessorhamphus ingolfianus.* Cephalic canal system in transitional adolescent, standard length 142 mm.; lateral view. (x 6.8).
Fig. 19 (Lower). *Nessorhamphus ingolfianus.* Hyoid and branchial apparatus in transitional adolescent, standard length 142 mm. (x 17.5).

falling between the first and second branchiostegal rays. There is no trace of separate epi- or interhyals. Articulation with the inner face of the hyomandibular is near the ventral border of the latter, about midway between quadrate and opercle. There are six or seven branchiostegals, the number sometimes varying on the two sides of the same specimen. These bones are always very slender, even basally, and only delicately ossified. Their posterior ends are curved forward, lying free in the branchial cavity. The last branchiostegal arises very close to the base of the preceding ray, and is only indirectly attached to the bone. A needle-like urohyal, its anterior end swollen, arises between the bases of the ceratohyals and extends posteriorly as far as the origin of the third gill arch.

Branchial Apparatus: (Fig. 19). The branchial arches lie between the posterior end of the opercle and the cleithrum, the bones lying almost horizontally, on a parallel with the upper edge of the opercle and overlapping each other throughout.

Three ossified, widely separated basibranchials show plainly in the Bermuda specimens. The first is triangular, the apex anterior, and lies against the upper surface of the attenuated end of the glossohyal. The second is slender and small, the third very small. The latter was completely lacking in Trewavas's example.

Hypobranchials are present in the first two arches, the second bone being half as long as the first. All five ceratobranchials are well developed, the first four of equal size—as long as the ceratohyal, but more slender—the fifth only half as long. The first two are deeply forked at their postero-dorsal tips, and their whole central regions scarcely ossified; the third is closed distally, but has an oblong terminal foramen; the fourth is fairly well ossified throughout, while the small fifth ceratobranchial is the strongest of all and bears an irregularly double series of conical teeth. There are four epibranchials, the first two minute and oval, the third long, and the fourth elongate and altogether more than five times as large as the first. Two pharyngobranchials are practically joined by suture, lying internal and immediately ventral to the third and fourth epiotics. Their dentigerous surfaces are opposed to the corresponding face of the fifth ceratobranchial. The anterior pharyngobran-

chial has only about half a dozen teeth, all confined to its postero-
ventral surface; the other bone, however, has one entire surface
covered with about forty conical teeth, arranged in roughly
diagonal rows of seven or eight teeth each.

Pectoral Girdle: (Fig. 17). The doubly-curving supra-
cleithrum is placed at the level of the anterior part of the eighth
vertebra, with which, however, it has no direct connection. The
cleithrum continues the girdle ventrally, curving forward in its
lower portion. Both bones, though slender, are strongly ossified.
Between the upper end of the cleithrum and the uppermost pec-
toral finray are two tiny disks of bone, only partially ossified,
the hyper- and hypocoracoids. Four minute radials are visible,
with only traces of ossification. Only the anterior, upper eleven
of the thirteen pectoral rays have bony deposits, and these
throughout only their proximal portions.

Vertical Fins and Supports: (Fig. 20). The dorsal fin orig-
inates between the 17th and 18th vertebrae, the anal at the 75th.
Only the proximal halves of the dorsal rays are ossified, and
even here the stain dies out toward the end of the fin. The anal
rays are entirely unossified. Baseosts of both fins are well de-
veloped and stained, though less strongly in the case of the anal
supports. The same is true of the radials connecting the finrays.
These minute, horizontal bones must serve the same purpose, in
aiding the forward migration of the vertical fins during meta-
morphosis, as do the analagous elements in the quite unrelated
Idiacanthus (Beebe 1934, p. 213). There are usually two fin-
rays to each vertebra.

Vertebral Column: (Fig. 20). The count of 150 vertebrae
for the largest cleared-and-dyed specimen includes both the first
element, which is fused to the skull, and the urostyle. Ossifica-
tion is strong only toward the end of the column. The vertebrae
are all of similar length (about .8 mm.) as far back as the 135th
element. Posterior to this they decrease in size and the last
form the specialized support for the caudal fin (see p. 45).

The dual character of the column—its formation around
the original neural tube and notochord—is very evident in this
species, and particularly in the immature specimen under dis-
cussion. Each centrum of typical, hour-glass, adult shape, is
attached by distinct suture to the exceedingly large, parallelo-
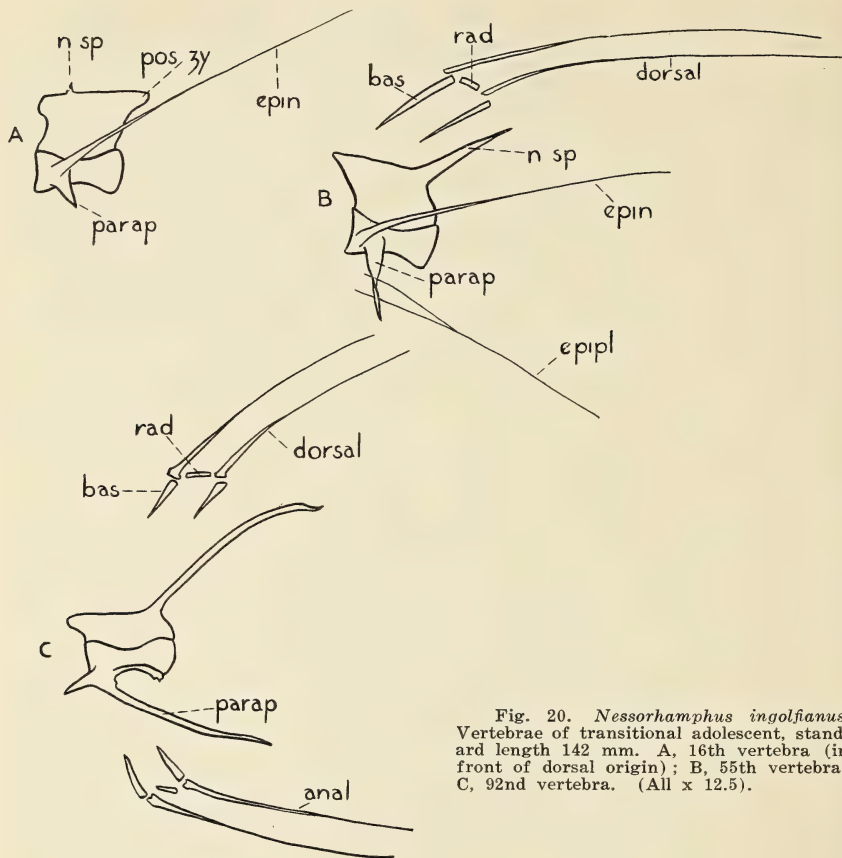
Fig. 20. *Nessorhamphus ingolfianus.* Vertebrae of transitional adolescent, standard length 142 mm. A, 16th vertebra (in front of dorsal origin); B, 55th vertebra; C, 92nd vertebra. (All x 12.5).

grammatic neuropophysis, this element equalling or exceeding the centrum in height.

The neural arches slope backwards and upwards in the first sixteen or seventeen vertebrae, the neural spine being small and near the anterior end of the arch. Posterior to this, the direction of the slope is reversed, and the neural spine shifts gradually to the posterior end of the arch, increasing progressively in size backward.

The first vertebra gives rise to three epineurals on the left side of the Bermuda specimen, and, possibly, on the right side also; Trewavas shows two in her figure. These extra elements may be vestiges of former vertebrae. Posterior to the pectoral fin

the epineurals are forked proximally. They die out at about the 124th vertebra. Throughout the length of the fish each epineural measures about three times as long as a centrum.

The centrum of the first vertebra is very short and lacks parapophyses. Between this and the pectorals the parapophyses are small and widely separated by median lamellar projections of irregular shape. Behind the pectorals the parapophyses become longer and more ventral, and arise directly from the lamellae, which are found in more lateral positions. From the dorsal origin backward the parapophyses shift gradually to the forward end of the centra, and each lamella extends the full length of the centrum, forming anterior and posterior zygopophyses toward the end of the caudal peduncle.

There are no pleural ribs.

Epipleurals are traceable from the 40th (37th in Trewavas's specimen) vertebra to the 124th, the same point at which the epineurals vanish. They are of similar length, and are forked proximally.

Posterior Part of Vertebral Column and Caudal Fin: (Fig. 21). There is remarkably little specialization of precaudal vertebrae up to the very urostyle segment itself. What change there is consists altogether of size, the individual vertebrae becoming gradually smaller from the 144th or seventh precaudal, which measures .54 mm. in length, to the 150th or last before the urostyle, which is only .24 mm. in length. The rounded articulating anterior part of the urostyle segment gives rise at once to a bony urostyle, longer than any of the precaudal vertebrae. This supports a well-developed neural arch, closely approximating in size and shape that of the precaudal elements.

From the ventral side of the urostyle arise three bony bases for the hypurals. The most superior one flares out into a fan shape, whose truncate posterior aspect supports the upper six of the twelve caudal rays. The second and third bases arise as stout pillars, and fuse over their posterior ends enclosing a large oval foramen. This entire plate supports four more of the rays. A fourth hypural articulates at its base with the prolonged haemal arch of the 150th vertebra, and an inferior facet of the third hypural base. The slightly expanded tip of this hypural
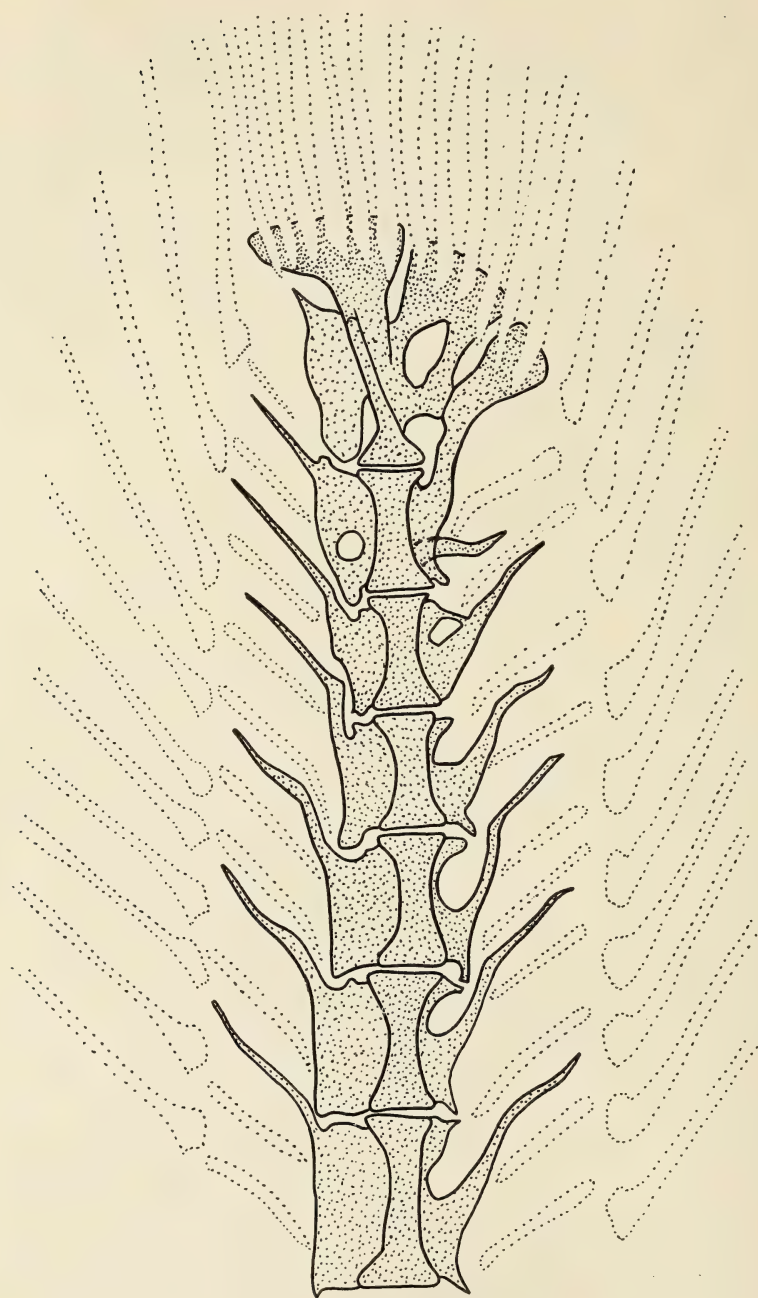
Fig. 21. *Nessorhamphus ingolfianus.* End of vertebral column and base of caudal fin of transitional adolescent, standard length 142 mm. (x 58).
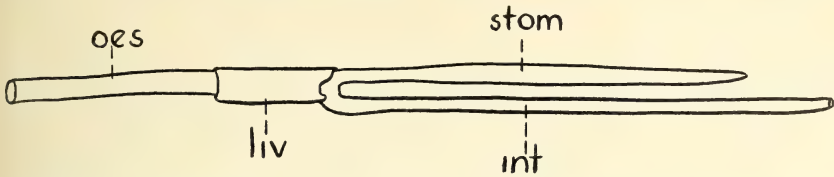
Fig. 22. *Nessorhamphus ingolfianus.* Alimentary canal of transitional adolescent, standard length 142 mm. (x .8).

supports the last two of the twelve caudal rays. All of these rays are strongly ossified for a considerable distance.

Digestive System: (Fig. 22). This is of the simplest. The blind sac stomach in our largest transitional adolescents is unpigmented and falls short of the anus. The pylorus is a snout's length behind the level of the pectoral base, at the posterior end of the single-lobed liver. The anterior end of the liver lies only several millimetres behind the pectoral base. The gall bladder is small and is placed immediately anterior to the pylorus.

Urino-genital System: The kidneys are uniformly slender and extend the full length of the coelomic cavity. They contain pigmented matter similar to that commonly found in these organs in certain families of this group.

The gonads are rudimentary, and appear as slender threads along the roof of the coelom.

RELATIVE BODILY PROPORTIONS: The following table shows the relative proportions of *Nessorhamphus* at different ages:

Growth Stage	Length Depth	Length Head	Head Eye	Head Snout	Length Snout to Dorsal	Length Snout to Anal	Pre-anal Myomeres
Larva (26, 28 mm.) (Present Series)	7.— 7.8	8.6— 9	6.5— 5.8	2.1— 2.2	1.8	1.1	120-121
Post-larvae (68 to 72 mm.) (Present Series)	7.4— 9.6	8.5— 7.4	8.2— 9.7	2.5— 2.2	4.4— 4.8	1.5— 1.7	89-78
Adolescents (81, 78 mm.) (Present Series)	18.— 20.	7.8— 6.4	7.4— 8.7	2.— 2.2	5.	1.8	72-73
Transitional Adolescents (80 to 166 mm.) (Present Series)	29.5— 30.	6.2— 6.	9.5— 10.7	2.6— 2.5	4.8— 4.6	1.9— 1.8	72-73
Adult (248.5 mm.) (Type Specimen)	25.	7.2	10.6	2.4	4.8	1.8	72 (vertebrae)

ECOLOGY

SEASONAL AND VERTICAL DISTRIBUTION: According to Schmidt, *Nessorhamphus ingolfianus* spawns at or near the surface of the Sargassum Sea in spring and early summer, somewhat later in the east than in the west, and the metamorphosis of the larva takes place in August, September and October at lower levels. The present material lends corroboration. In the spring only large transitional adolescents were captured off Bermuda; no small larvae have been taken there, the only larvae of any length being two half-grown leptocephali caught early in September; finally, all of the metamorphosing specimens occurred in August and September, in deep water.

ABUNDANCE: *Nessorhamphus* is rare among the deep-sea fish captured off Bermuda, only once occurring in every 52.5 nets drawn between 400 and 1,000 fathoms, the Bermuda limits of its distribution.

SOCIABILITY: Only twice were more than a single specimen taken in the same net; in each of these cases two transitional adolescents of similar size came up together.

FOOD: The stomachs of six transitional adolescents, between 87 and 166 mm., were found to contain remains of schizopods or shrimps. These were distributed as follows:

Length of Nessorhamphus	Food	Length of Food
85 mm.	1 *Thysanopoda*	20 mm.
87 mm.	1 *Thysanopoda*	11 mm.
88 mm.	1 shrimp or schizopod; much digested.	
125 mm.	3 *Thysanopoda*	17 to 23 mm.
141 mm.	3 Shrimps or schizopods; small; much digested	
166 mm.	1 *Sergestes*	31 mm.

In every case the crustaceans had been swallowed tail first. An 80 mm. specimen had eaten radiolarians.

ENEMIES: *Nessorhamphus* has not yet been found in the stomach of any other animal.

VIABILITY: We have not taken *Nessorhamphus* alive in our nets. Captain Hansen and Dr. Tåning, however, both succeeded in hatching the eggs on board ship, and in raising the pre-larvae to a stage where comparison could be made with pre-larvae of known identity caught swimming in the water.

STUDY MATERIAL

The following list gives the catalogue number, depth in fathoms, date of capture, length and growth stage of each specimen of *Nessorhamphus ingolfianus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in ZOOLOGICA, Vol. XVI, No. 1, p. 5. "Trans. Adol." stands for "Transitional Adolescent."

No. 9,568; Net 24; 700 F.; April 15, 1929; 125, 135 mm.; Trans. Adol.
No. 9,751; Net 64; 600 F.; May 4, 1929; 141 mm.; Trans. Adol.
No. 12,499; Net 385; 600 F.; Aug. 17, 1929; 70 mm.; Post-larva
No. 13,561; Net 460; 700 F.; Sept. 11, 1929; 88 mm.; Trans. Adol.
No. 16,030; Net 707; 500 F.; June 16, 1930; 142 mm.; Trans. Adol.
No. 17,748; Net 834; 400 F.; Sept. 3, 1930; 85 mm.; Trans. Adol.
No. 17,819; Net 842; 600 F.; Sept. 4, 1930; 78 mm.; Adolescent
No. 18,024; Net 855; 700 F.; Sept. 6, 1930; 92 mm.; Trans. Adol.
No. 18,058; Net 859; 500 F.; Sept. 8, 1930; 69 mm.; Post-larva
No. 18,082; Net 861; 700 F.; Sept. 8, 1930; 68 mm.; Post-larva
No. 18,601; Net 890; 600 F.; Sept. 15, 1930; 80 mm.; Trans. Adol.
No. 19,274; Net 940; 1,000 F.; Sept. 24, 1930; 81 mm.; Adolescent
No. 23,041; Net 1,245; 1,000 F.; Aug. 31, 1931; 70 mm.; Post-larva
No. 23,126; Net 1,263; 800 F.; Sept. 4, 1931; 28 mm.; Larva
No. 23,292; Net 1,287; 1,000 F.; Sept. 10, 1931; 26 mm.; Larva
No. 23,550; Net 1,312; 400 F.; Sept. 16, 1931; 72 mm.; Post-larva
No. 23,565; Net 1,313; 500 F.; Sept. 17, 1931; 87, 87 mm.; Trans. Adol.
No. 23,600; Net 1,314; 600 F.; Sept. 17, 1931; 166 mm.; Trans. Adol.
No. 23,636; Net 1,324; 400 F.; Sept. 18, 1931; 84 mm.; Trans. Adol.

SYNONYMY AND REFERENCES

Leptocephalus ingolfianus:
   Schmidt, 1912, p. 49, pl. III, fig. 8. (Description of larva).

Avocettina scapularostris:
   Borodin, 1929, p. 109. (1 specimen; 153 mm.; 41° 29′ N. Lat., 47° 48′ W. Long.; 800-0 fathoms).
   Borodin, 1931, p. 74, pl. 3, figs. 1-3. (Supplementary description of preceding specimen).

Nessorhamphus ingolfianus:
   Schmidt, 1930, p. 273, pls. IV-V. (Type description; résumé of development. Many thousand specimens from North Atlantic, surface to deep water, in collection; eggs and fish of all lengths up to at least 248.5 mm.).
   Trewavas, 1932, p. 652, pl. IV, text figs. 7-9. (Osteology).
Parr, 1932, p. 19. (1 specimen; 125 mm.; 23° 24′ 15″ N. Lat., 64° 29′ W. Long.; 10,000-foot wire).

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1931b　Bermuda Oceanographic Expeditions 1929-1930. List of Nets and Data. ZOOLOGICA, Vol. XIII, No. 2.

1932　Bermuda Oceanographic Expeditions 1931. Individual Nets and Data. ZOOLOGICA, Vol. XIII, No. 3.

1933a　Deep-sea Fishes of the Bermuda Oceanographic Expeditions. Introduction. ZOOLOGICA, Vol. XVI, No. 1.

1933b　Deep-sea Fishes of the Bermuda Oceanographic Expeditions. Family Alepocephalidae. ZOOLOGICA, Vol. XVI, No. 2.

1933c　Deep-sea Fishes of the Bermuda Oceanographic Expeditions. Family Argentinidae. ZOOLOGICA, Vol. XVI, No. 3.

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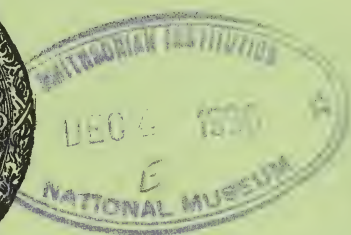
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DEEP-SEA FISHES OF THE BERMUDA
OCEANOGRAPHIC EXPEDITIONS

No. 3—Family SERRIVOMERIDAE

WILLIAM BEEBE
&
JOCELYN CRANE

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

FAMILY SERRIVOMERIDAE

Part I: Genus Serrivomer[1]

WILLIAM BEEBE and JOCELYN CRANE

Department of Tropical Research, New York Zoological Society

(Figs. 23-42 incl.)

CONTENTS

INTRODUCTION

For detailed data in regard to nets, locality, dates, etc. concerning the capture of the deep-sea eels treated in this monograph, refer to ZOOLOGICA, Vol. XIII, Nos. 1, 2 and 3 and Vol.

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[1] Contribution No. 505, Department of Tropical Research, New York Zoological Society.

XX, No. 1, pp. 1-2. For physical data, methods of measurement and definitions of growth stages, see ZOOLOGICA, Vol. XVI, No. 1.

The drawings in the present papers are the work of George Swanson.

Our thanks are due to the following persons for their co-operation in enabling us to examine specimens of *Serrivomer* deposited in various museums: Dr. George S. Myers of the U. S. National Museum, Miss Erna W. Mohr of Ahrensburg, Germany; Dr. Albert Eide Parr and Y. H. Olsen of the Peabody Museum, New Haven, and the summer custodian of the collections of the Museum of Comparative Zoology in Cambridge.

IMPORTANT POINTS IN THE FOLLOWING STUDY OF SERRIVOMER

TAXONOMY AND DISTRIBUTION: The recorded specimens of *Serrivomer* comprise three distinct species, *S. beanii* Gill and Ryder 1883 and *S. brevidentatus* Roule and Bertin 1929, both confined to the Atlantic Ocean, and *S. sector* Garman 1899, confined to the Pacific and Indian Oceans.

ECOLOGY AND DEVELOPMENT: *S. beanii* is the most common deep-sea eel found in our Bermuda trawling area, although it is a rare fish compared with *Cyclothone signata, Cyclothone microdon, Sternoptyx diaphana* and certain paralepids and myctophids. *S. sector*, on the other hand, is one of the rarest of all the fishes in the region.

The jaws of members of the genus *Serrivomer* are long and strong with numerous fine, sharp teeth, while there is a long, saw-like ridge of large, compressed teeth on the vomer; the stomach is only moderately distensible; the digestive organs are crowded into the anterior one-sixth of the fish; the principal foods of the eels and elvers are shrimps and euphausids (chiefly of one genus), with occasional myctophids and cyclothones, while the leptocephalids eat diatoms and minute crustaceans.

Bathysphere observations of *Serrivomer* showed that these eels are brilliantly iridescent, fast swimmers, and travel alone, in pairs and in groups of four or five; they were recognized on six different occasions, between 125 and 250 fathoms. They have been taken in the trawling nets off Bermuda between 50 and 1,000 fathoms and elsewhere down to 3,281 fathoms. No satis-

factory correlation has been found between depth and growth stage, as large fish were seen from the Bathysphere much higher than eels of equal size were caught in the nets, whereas larvae were caught at very low, as well as at high levels. Off Bermuda there seems to be a chief breeding season in late spring and early summer.

The larva of *Serrivomer* is a typical leptocephalus, distinguishable by its moderate depth (7.8 to 10 in length), long snout and characteristic number of myomeres (a total of 154 to 165, of which 89 to 97 are preanal). It grows to about 63 mm. in length before metamorphosis, which takes place rapidly. Elvers of 100 mm. have all the general characters of the adults. The great majority of the Bermuda specimens are immature fish measuring between 100 and 300 mm. Probably no fully adult fish is less than 500 mm. in length. The largest known specimen is the type, 594 mm. long. It seems likely that individuals breed only once, as is the case with *Anguilla*. All of the Bermuda specimens in which the sex can be determined are females.

GENUS *Serrivomer*, WITH A TAXONOMIC REVISION OF THE SPECIES

GENERIC CHARACTERS: Snout less than half length of head; gradually tapering, not sharply constricted, in front of eye; vomerine teeth forming a high, serrated ridge along roof of mouth. Trunk decreasing gradually in height and thickness from shoulder to tail; no nuchal constriction; no caudal filament; jaws strong, the lower slightly the longer; maxillary teeth strong and pointed, in several rows; mandibular teeth similar; vomerine teeth large, flattened, triangular, forming the above-mentioned serrated ridge along the roof of the mouth; pectorals rudimentary; dorsal beginning well behind pectorals and continuing to the tip of the tail; anal origin immediately behind anus, at a distance about mid-way between pectoral base and dorsal origin, and continuing to the end of the body; posterior portions of dorsal and anal fins lax, not forming a pseudo-caudal; about 30 anal rays in the last 3.5 per cent of the total length of the fish, and about 20 rays occupying a space per ray of less than one-tenth of one per cent. of the total length; branchial clefts confluent; lateral line without pores, or with a

single series of small, inconspicuous pores immediately below it. Three species.

DISCUSSION AND TAXONOMIC REVISION OF THE SPECIES: Due both to the inadequacy of the early descriptions of the species of *Serrivomer* and to the scattered locations of the various collections, the validities of the described species have always been questionable. The present discussion should, however, clear up the major taxonomic issues for, in addition to studying in detail our extensive Bermuda collection, we have been able to examine the following specimens: the type of *S. beanii* Gill and Ryder 1883 (U. S. National Museum, Washington, D. C.) ; the type of *S. sector* Garman 1899 and the other Pacific specimens of the *Albatross* collection (Museum of Comparative Zoology, Cambridge, Mass.) ; four of the six *Valdivia* specimens from the East Indies and the Indian Ocean (Berlin Museum and the Museum of Leipzig) ; nine specimens taken by the Bingham Oceanographic Expeditions from the Atlantic (Peabody Museum, New Haven, Conn.) ; four specimens of the Iselin Expedition in the North Atlantic; and, finally, a number of unrecorded specimens from the eastern Pacific and the Gulf of California taken, respectively, on the *Arcturus* Oceanographic Expedition (1925) and the Templeton Crocker Expedition (1936), both trips having been undertaken by this department of the New York Zoological Society. The only important collection which has not been inspected is that of the *Dana* Expedition of 1920-1922, but since these specimens were reported upon fully by Roule and Bertin in 1929, it has been found possible to establish, in a general way, the taxonomic status of this collection as well.

From our study, it is apparent that there are three distinct species of *Serrivomer*: *S. beanii* Gill and Ryder 1883 from the Atlantic, *S. brevidentatus* Roule and Bertin 1929 (described as *S. sector* type *brevidentatus*), which is also from the Atlantic, and *S. sector* Garman 1899, which is confined to the Pacific and Indian Oceans. (Fig. 23).

In the differentiation of the species, four main characters are involved, which may best be shown in the following tabular form:

	S. beanii (Atlantic)	*S. brevidentatus* (Atlantic)	*S. sector* (Pacific)
Vomerine teeth	50-80, 3-4 times as long as wide.	20-30, twice as long as wide.	like *S. beanii.*
Anterior tips of first 5 brr. rays	project far beyond hyoid element to which they are attached. (See Fig. 31).	project not at all. (See Fig. 40).	like *S. brevidentatus.*
Distance from snout to anal origin contained in length	4.0-4.5 times.	3.4-3.8 times.	like *S. brevidentatus.*
No. of anal rays	124-140	159-173	150-160

The dental characteristics described by Roule and Bertin (1929, p. 39) as distinguishing their two groups of specimens, *S. sector,* type *longidentatus* (= *S. beanii*) and *S. sector,* type *brevidentatus* (= *S. brevidentatus*) are fully corroborated by Bermuda specimens measuring more than 300 mm. in length: *S. beanii* differs from *S. brevidentatus* chiefly in having the teeth of the vomerine ridge longer and more numerous and in having those of the maxillary fewer and more scattered, there being a distinct row of much longer, more pointed teeth. The larger teeth of the mandible also, although no fewer than in *S. brevidentatus,* are longer and more slender in *S. beanii.* We have found in addition that the dentition of true *S. sector,* from the Pacific, is practically identical with that of *S. beanii.* The details of the dentition in the two forms may be presented as in the table on page 58.

Specimens of *Serrivomer* smaller than about 300 mm. are indistinguishable specifically on the basis of the dentition, since the teeth of all three species resemble those of adult *S. brevidentatus*: the vomerine ridge teeth are relatively short and broad, and few in number, while those of the maxillary and mandible are comparatively homogeneous. Therefore, since it is chiefly by means of the dentition that *S. sector* is distinct from *S. brevi-*

TABLE SHOWING THE RELATIVE DENTAL CHARACTERISTICS
OF THE SPECIES OF *Serrivomer.*

	S. beanii and S. sector	S. brevidentatus
Vomer	50-80 teeth on ridge, each tooth three to four times as high as wide, alternating in 2 parallel rows forming a ridge from anterior part of eye to point 4/5 of distance from eye to snout tip; elevation greatest in middle of ridge; its greatest height almost equals vertical diameter of eye. From end of ridge to snout tip are numerous small teeth irregularly arranged.	20-35 teeth on ridge, each tooth twice as high as wide; ridge extends from nostril to point 3/5 of distance from eye to snout tip, a little before maxillary's end; greatest height of ridge equals 2/3 vertical diameter of eye; otherwise identical with *S. beanii* and *S. sector.*
Maxillary	3 to 4 rows of teeth, increasing in size from outer to inner; the inner row is formed of 20 to 25 very long, needle-like teeth, sharply differentiated from those of the other rows. Teeth and bones end about 4/5 of preorbital distance.	3 rows of teeth, increasing in size from outer to inner; the inner row is formed of 30 to 40 teeth, only moderately larger than those of the other rows, and triangular in shape; otherwise identical with *S. beanii* and *S. sector.*
Mandible	3 to 5 rows of teeth, increasing in size from outermost to next to innermost row; innermost very small; 35 to 45 teeth, slender like the long teeth of the maxillary, in next to innermost row, this row ending about 3/4 of distance from eye to tip of jaw; from here on the arrangement is irregular.	4 to 6 rows of teeth; less varied than in the other species, the large teeth of the next to the innermost row being relatively shorter and broader; and ending about 3/5 of distance from eye to tip of jaw; otherwise identical with *S. beanii* and *S. sector.*

dentatus, we cannot distinguish the young of these two species, although there is no danger of confusing them since they inhabit different oceans. The young of the two Atlantic species, however, can be easily differentiated by the anal count and, more easily, by the mode of attachment of the branchiostegal rays to the hyoid arch. In *S. brevidentatus,* the first five rays are fastened to the hyoid bones in the usual manner, by the extreme anterior tips of the rays. In *S. beanii,* on the other hand, each
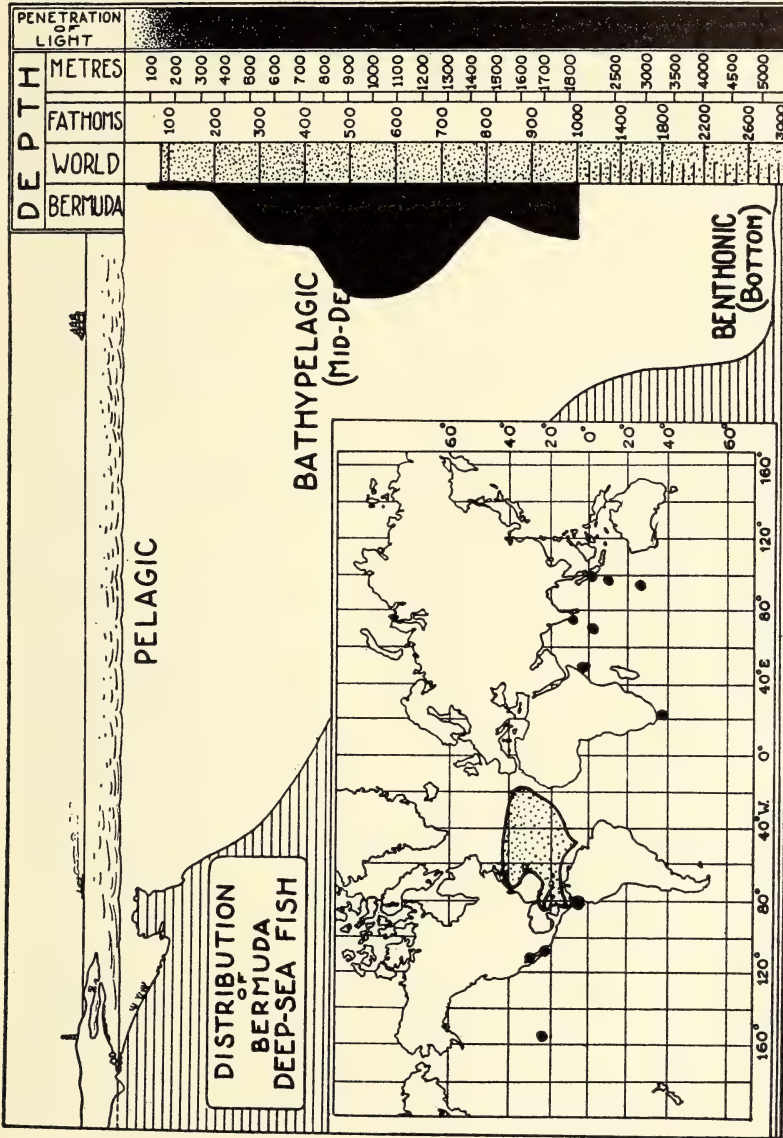
Fig. 23. The geographical and vertical distribution of the genus *Serrivomer*. The shaded area in the Atlantic Ocean indicates the range of the two species, *S. beanii* and *S. brevidentatus*; the specimen marked by the circle at the tip of South Africa is of questionable identity; all others are *S. sector*. The relative numbers of specimens of *Serrivomer* taken at different depths by the Bermuda Oceanographic Expeditions are shown diagrammatically at the left of the column which gives the vertical range of the genus.

corresponding ray projects considerably in front of the hyoid element to which it is attached. If the specimen is turned on its back and the angles of the jaw are separated as far as possible with forceps, this character can almost always be determined without even rupturing the skin; this character develops earlier than any of the others of specific value, being determinable even in post-larvae. We have not, however, been able to find a means by which the larvae (true leptocephali) of the Bermuda collection can be separated. The only character of possible value at this stage is the anal ray count, but as the full complement of rays is found only in the oldest larvae, the count is not of help in the majority. Since all of the 15 larvae in the Bermuda collection are so similar, and since, in a total of 147 older specimens, all except seven are *S. beanii*, it is assumed in this paper that the larvae are all of this species.

From a study of the skeletons of Bermuda specimens, the following remaining differences were discovered between the two Atlantic species, *S. beanii* and *S. brevidentatus*: In *S. beanii* the ethmo-vomer is more robust, in evident correlation with the heavier burden of teeth; the preopercle is more extensive and the opercle triangular rather than quadrilateral; there are differences in the vertebrae, the most conspicuous being the great length of the neural spine; and, finally, in all specimens examined, including the type of *S. beanii*, the anal fin has only 126 to 140 rays, instead of the 159 to 173 found in *S. brevidentatus*. Roule and Bertin, however, state (*loc. cit.*) that in their series the dorsal and anal each numbered about 160 to 161 rays; it seems possible that they did not happen to count the anal rays in any of their "type *brevidentatus*" group. No differences in coloration, remarked upon by Roule and Bertin, are discernible in Bermuda specimens of the two species.

In summary, *S. beanii* differs from *S. sector* in the greater development of the bones throughout the skeleton, as evidenced in the skull, teeth, opercular and hyoid apparatus, and in the vertebral column. None of the differences can be attributed either to age or sex, and as both forms occur in the same locality, there can be no question of geographical race or subspecies.

Of the three species of *Serrivomer*, about 145 specimens have previously been recorded from the Atlantic, Pacific and

Indian Oceans. They measured between 103 and 629 mm. and were taken down to a depth of 3,281 fathoms (6,000 metres). The following annotated synonymies of the three species, based on the reexamination of the actual specimens or upon a study of the published data, as indicated, are for convenience herewith presented together:

1. Serrivomer beanii Gill and Ryder 1883

Serrivomer beanii:

Gill and Ryder, 1883, pp. 260-261. 1 specimen; 594 mm.; 41° 40′ 30″ N. Lat., 65° 28′ 30″ W. Long., about 200 miles east of Nantucket; 855 fathoms. (Specimen reexamined; it is typical in every way of the specimens which have been taken more recently).

Goode and Bean, 1895, p. 155, fig. 175. (Supplementary description of preceding specimen).

?Barnard, 1925, p. 200. 1 specimen; ? mm.; south of Agulhas Bank, South Africa. (Since we were not able to examine this specimen, and since it was taken on the boundary line between the Atlantic and Indian Oceans—i.e. between the known ranges of *S. beanii* and *S. sector*—the identity of this specimen remains questionable.)

Nemichthys infans:

Vaillant, 1888, p. 93, pl. vii, Figs. 1, 1a. 1 specimen; 240 mm.; 2,995 metres; off Azores. (We refer this specimen with little hesitation to *S. beanii* although we have not been able to examine it, because, from Vaillant's published measurements, the distance from the snout to the anal origin is contained 4.5 times in the length of the fish, this proportion being typical of *S. beanii* and not of *S. brevidentatus*, the other Atlantic species. Vaillant mentions that the anal fin is badly damaged, and the small size of the specimen would make the dentition of little value in specific determination. The fourth character, the mode of attachment of the branchiostegal rays, is unknown).

Nemichthys richardi:

Vaillant, 1888, p. 385. Above specimen designated as new species.

Serrivomer richardi:

Goode and Bean, 1895, p. 155. Above specimen referred to *Serrivomer.*

Serrivomer sector:

Roule and Bertin, 1929, p. 35. Above specimen verified as a *Serrivomer,* from a reexamination of the type by Roule and Bertin.

ibid., pp. 39-47, *part.* An indeterminable number of specimens, measuring between 79 and 629 mm. in length, taken between 150 and 6,000 metres in the North Atlantic (comprising all the specimens referred to *S. sector* type *longidentatus* with the exception of those taken in the Gulf of Panama).

Parr, 1932, pp. 2-3. 7 specimens; 186 to 291 mm.; 4,000 to 8,000 feet of wire; Bahamas and Bermuda. (Reexamined by the present authors and found to be typical *S. beanii*).

Gavialiceps microps:

Borodin, 1931, p. 74. 2 specimens; 216, 252 mm.; 1,500 metres; off Bermuda. (Reexamined by the present authors and found to be typical *S. beanii*).

Incertae sedis:

Parr, 1932, p. 3, *part.* 2 specimens; 126, 128 mm.; 10,000 feet of wire; off Bermuda. (Reexamined by the present authors and found to be typical *S. beanii*).

Serrivomer sp.

Beebe, 1933, p. 180, *part.* Preliminary note of specimens of *Serrivomer* taken by the Bermuda Oceanographic Expeditions.

Serrivomer sector longidentatus:

    Parr, 1934, p. 6. 1 specimen; ? mm.; 1,050-1,100 metres;
      Bahamas.

2. **Serrivomer sector** Garman 1899

Serrivomer sector:

    Garman, 1899, pp. 320-323, pl. LXIII. 11 specimens; up to
      570 mm.; 134 to 1,772 fathoms; 9 stations off Colombia,
      from 325 miles west of Bahia del Choco to just south of
      Cape Mala, Panama; 1 station in Gulf of California, 50
      miles south of Guaymas. (Reexamined by the present
      authors).

    Brauer, 1906, p. 132, pl. VIII, fig. 4. 6 specimens; 205 to
      392 mm.; 1,213 to 2,400 metres; Indian Ocean: between
      New Amsterdam and Sumatra, Binnen Bay on the west
      coast of Sumatra, west of Chagos Archipelago, and off the
      coast of Italian Somaliland. (4 of the specimens—3
      from the Sumatra and Sumatra-to-New Amsterdam re-
      gions and 1 from off Somaliland—have been reexamined
      by the present authors. In spite of the fact that the ex-
      amples are not in good condition and that two of them,
      including the one from Somaliland, measure only 205
      and 210 mm. respectively, still enough characters remain
      in the group as a whole to show that these individuals do
      not differ specifically from those taken in the eastern
      Pacific: in no specimen do the branchiostegal tips overlap
      the hyoid elements as in *S. beanii;* the two largest [330 and
      392 mm.] are old enough to show typical *S. sector* dentition;
      in the three specimens where the measurement could be
      taken, the snout-to-anal distance is contained 3.6 to 3.8
      times in the length; and, finally, the anal count of the largest
      example [the fins of all others are damaged] is 152).

    Lloyd, 1909, p. 152. 1 specimen; ? mm.; 930 fathoms; Arabian
      Sea, off Travancore.

    Weber and Beaufort, 1916, pp. 331-332, text-fig. 160. Mention
      of known Pacific specimens.

    Townsend and Nichols, 1925, p. 12. 2 specimens; 485 and ?

mm.; 590 and 630 fathoms; Gulf of California, off Todos
Santos Bay and off Cape San Lucas, respectively.

Roule and Bertin, 1929, pp. 39-47, *part.* An indeterminable
number of specimens, measuring between 79 and 629 mm.
in length, taken, between 150 and 6,000 metres, in the Gulf
of Panama. (Probably these specimens were among those
referred to *S. sector* type *longidentatus*).

Serrivomer beanii:

Gilbert, 1905, p. 386. 3 specimens; 311 to 1,067 fathoms;
Hawaiian Islands.

3. **Serrivomer brevidentatus** Roule and Bertin 1929

Serrivomer sector:

Roule and Bertin, 1929, *part.* An indeterminable number of
specimens, measuring between 79 and 629 mm. in length,
taken between 150 and 6,000 metres in the North Atlantic
(comprising all the specimens referred to *S. sector* type
brevidentatus).

?Trewavas, 1932, p. 650, pl. III. 1 specimen; 160 mm.;
depth ?; locality ? Description of the skull. (The illustra-
tion shows that this specimen is unquestionably not *S.
beanii.* In placing it under *S. brevidentatus* instead of un-
der *S. sector,* we are assuming that it was captured in the
Atlantic rather than in the Pacific or Indian Ocean).

Serrivomer sp.

Beebe, 1933, p. 180, *part.* Preliminary note of specimens of
Serrivomer taken by the Bermuda Oceanographic Expedi-
tions.

Note: The specimens of *Serrivomer* and *Serrivomer*-like
fish, which have been recorded by Beebe (1933a and 1934) as
observed from the Bathysphere, may obviously have belonged
to either or both of the Bermuda species of *Serrivomer* and pos-
sibly to the genus *Platuronides* as well, since all of these forms
are superficially much alike.

The specimens recorded by Borodin, 1931, p. 74, from near Bermuda as *Serrivomer sector* proved upon reexamination by us to be adolescent nemichthyids.

The Bermuda Oceanographic Expedition specimens of *S. beanii* and *S. brevidentatus* will now be discussed in detail.

Serrivomer beanii Gill and Ryder 1883

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

155 specimens; April to October, 1929 to 1931; 50 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 55 to 440 mm.

DESCRIPTION OF ADULT
(Figs. 24J, 25J)

COLOR: Black, with a fragile coating of silver skin which, when fresh, has a high bronzy iridescence.

PROPORTIONS (from the three largest Bermuda specimens, standard lengths 400, 405, 440 mm., and the type specimen, standard length 596 mm.) : Depth in length 30 to 41; head in length 5.3 to 6.4; eye (horizontal) in head 16 to 17.2; eye is horizontally elongate; maxillary reaching well beyond vertical from posterior margin of eye; snout in head 2.4 to 2.8; snout to dorsal in length 3.1 to 3.3; snout to anal in length 4 to 4.3.

TEETH: The dentition has been described in detail on p. 58.

FINS: Pectoral rays 6 or 7, very delicate, equal in length to horizontal diameter of eye, inserted at upper angle of branchial cleft. Dorsal rays 159 to 165, commencing well behind the anal origin, at a distance 1.3 to 1.5 times the postorbital length of the head; the first dorsal ray is inserted above the eleventh to thirteenth anal ray. Anal rays 124 to 140, longer than those of dorsal. The rays of both fins are longest, and the spaces between successive rays greatest, in the anterior halves, behind the first 10 or 15 rays. Caudal rays 5 or 6, scarcely distinguishable from
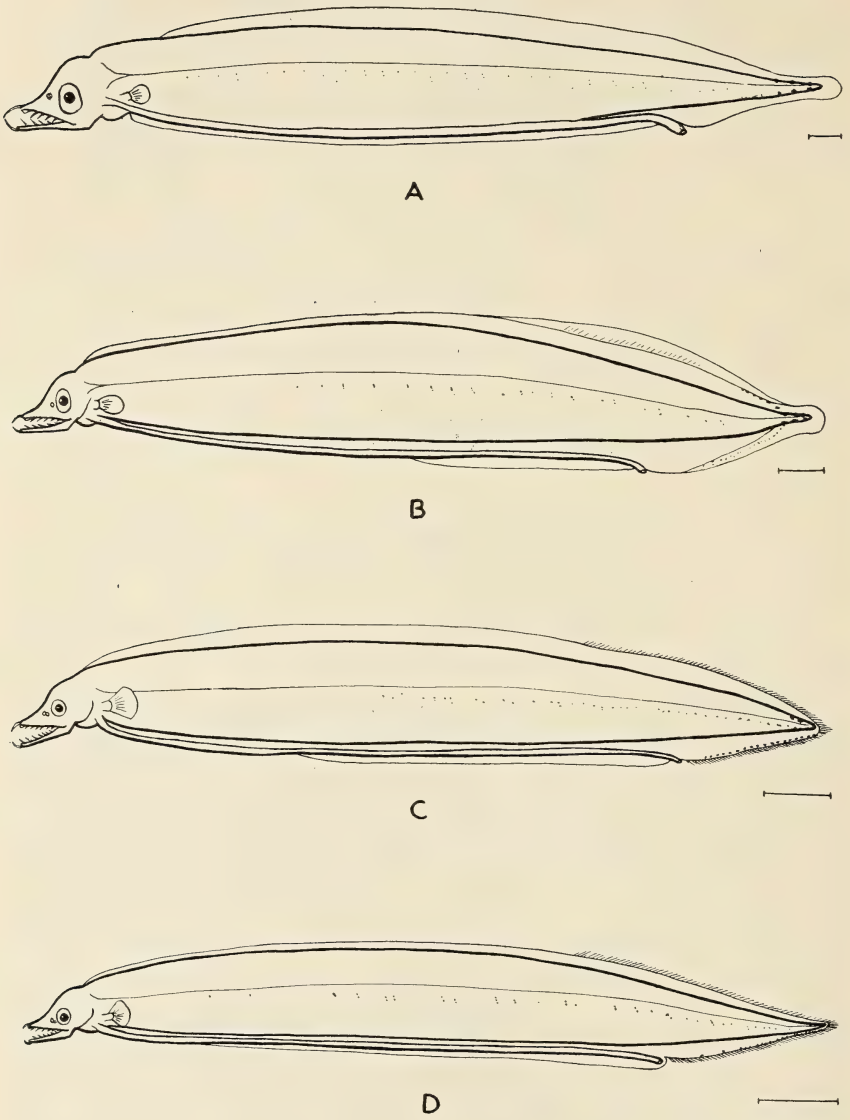
Fig. 24. *Serrivomer beanii*. A to D, incl., larvae, 17, 25, 36, and 43 mm., respectively.
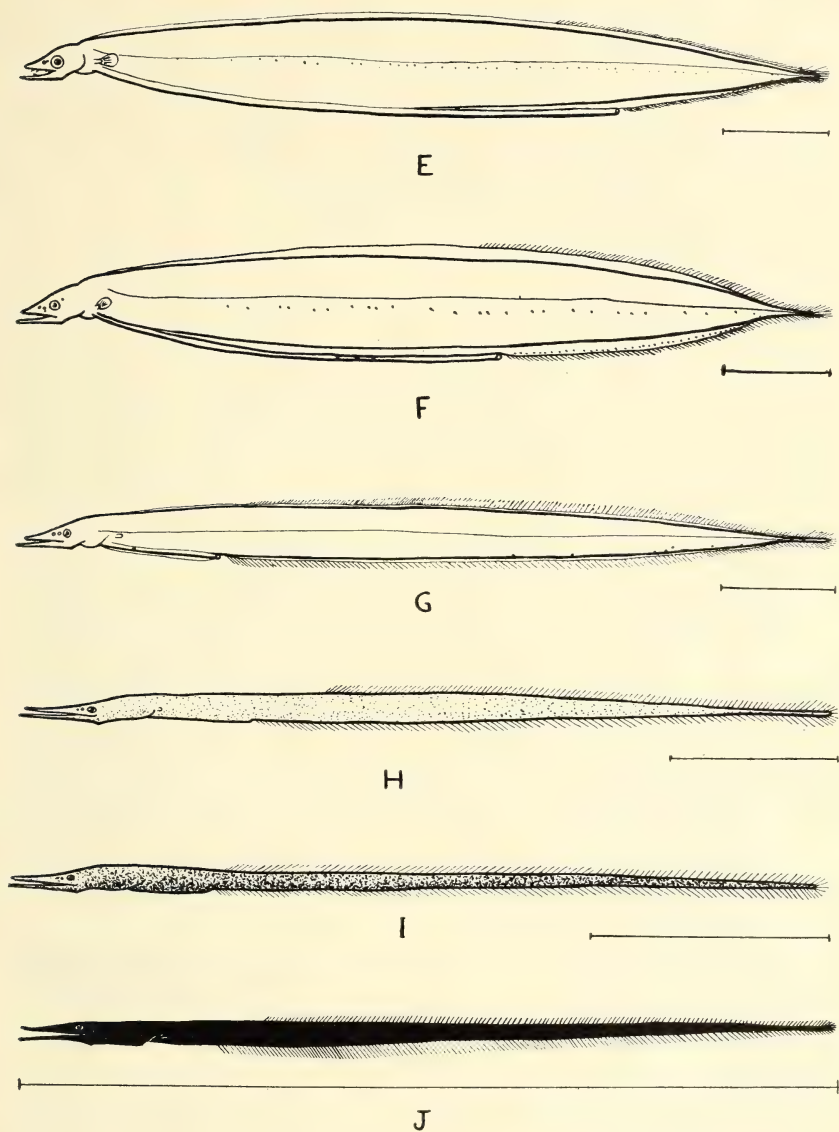
Fig. 24, cont. *Serrivomer beanii.* E, larva, 57 mm.; F, post-larva, 59 mm.; G and H, adolescents, 59 and 61 mm.; I, transitional adolescent, 127 mm.; J, adult, 440 mm.
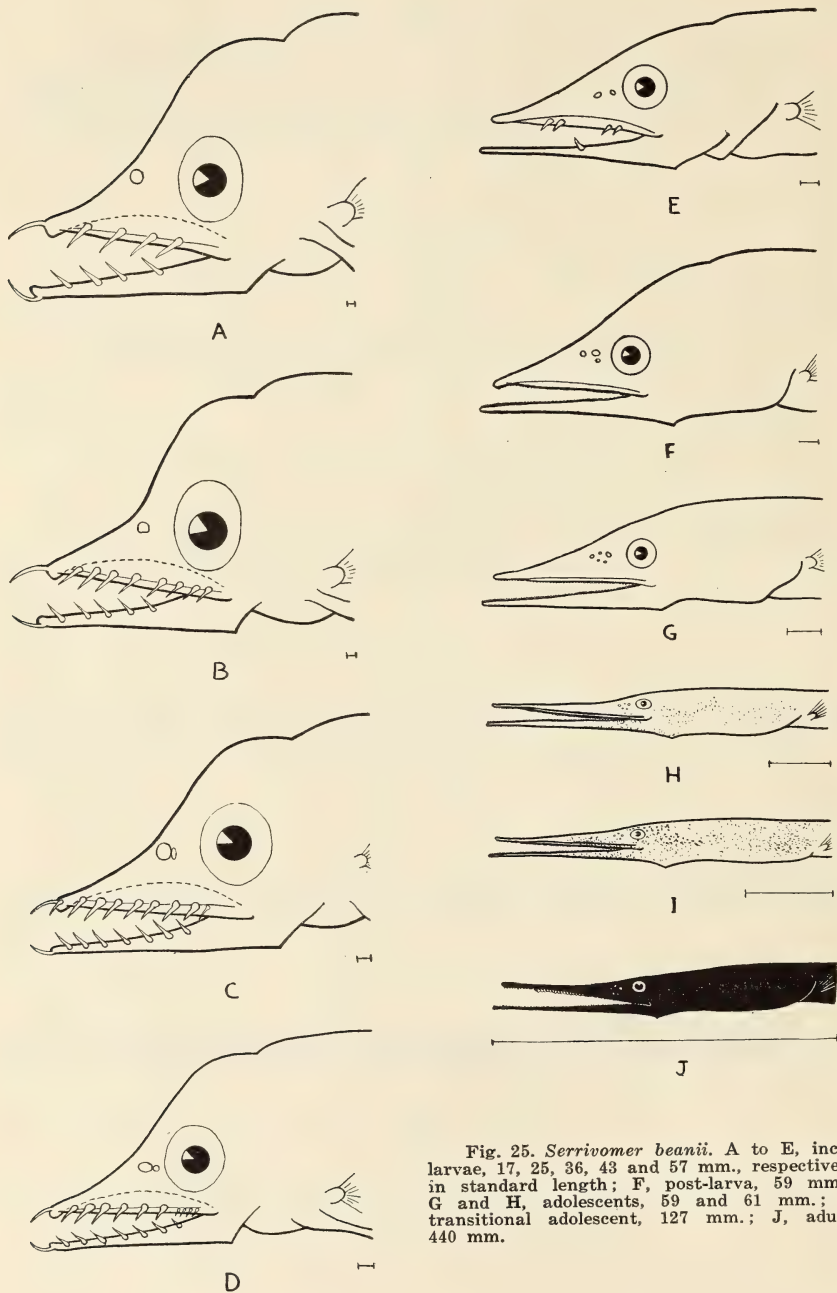
Fig. 25. *Serrivomer beanii.* A to E, incl., larvae, 17, 25, 36, 43 and 57 mm., respectively in standard length; F, post-larva, 59 mm.; G and H, adolescents, 59 and 61 mm.; I, transitional adolescent, 127 mm.; J, adult, 440 mm.

those of dorsal and anal, with which the caudal fin is confluent.

VERTEBRAE: Bermuda specimens, 154-168; specimens described by Roule and Bertin (1929, p. 41), 143 to 155.

OSTEOLOGY: (Figs. 28-33). The following description is derived from the largest (440 mm.) Bermuda specimen.

Skull: The skull and jaw from above are exceedingly elongate and slender. There is no supraoccipital, unless its vestiges are concealed beneath the epiotics, which are medially united by suture. They form the posterior third of an oval space, the anterior two-thirds of which are formed by the parietals. The paired frontals are narrow and long, bent midway so abruptly downward that they look like two pairs of bones. The sphenotics extend laterally as two large, triangular wings with the anterior face concave. Disregarding whatever part the vomer may play ventrad, the ethmoid or dorsal element is relatively enormous. Antero-posteriorly it occupies almost seven-eighths of the entire length of the head, and equals the frontals in extreme width. Posteriorly it narrows to a long, slender spear point which overlies the frontals to the vertical of the sphenotics.

Laterally the skull shows considerable depth. All the dorsal elements are visible in a narrow, elongate line. The epiotics are about twice the size of the supraoccipital and extend well back of that bone. Articulating with the parietals and extending back beneath and behind the epiotics are the pterotics, for once justifying their name. The alisphenoids are small and join the frontals and sphenotics. The parasphenoid is a slender rod extending from beneath the braincase forwards and merging with the dentigerous vomer somewhere beneath the covering palatines.

Palato-pterygoid Arcade: Each palatine shows an extended base along the lateral ethmoid. The pterygoid is large, triangular, set in unossified tissue between the maxillary and ethmoid, and sends a long, thin rod down and backward to the articulation of the hyomandibular and quadrate with the jaw angle.

The hyomandibular has been drawn out into an almost indescribable shape: A long rod extends almost to the articulation of the lower jaw, then a stout anterior projection, matching but not touching the posterior outline of the pterygoids; posteriorly another long rod underlies the pterotic, while to the lower face is applied the short and wide quadrate.
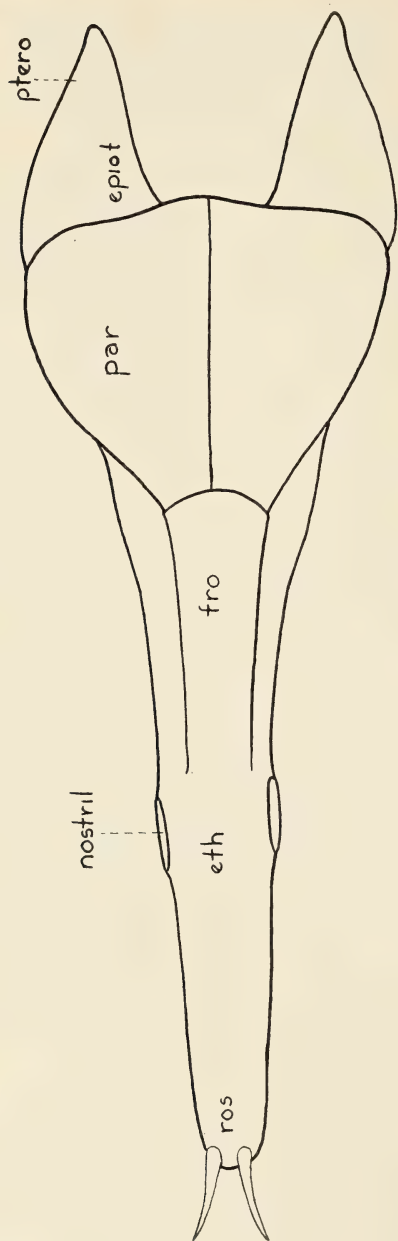
Fig. 26. *Serrivomer beanii.* Cartilaginous elements of larval skull, dorsal view. Standard length 36 mm. (x 44).
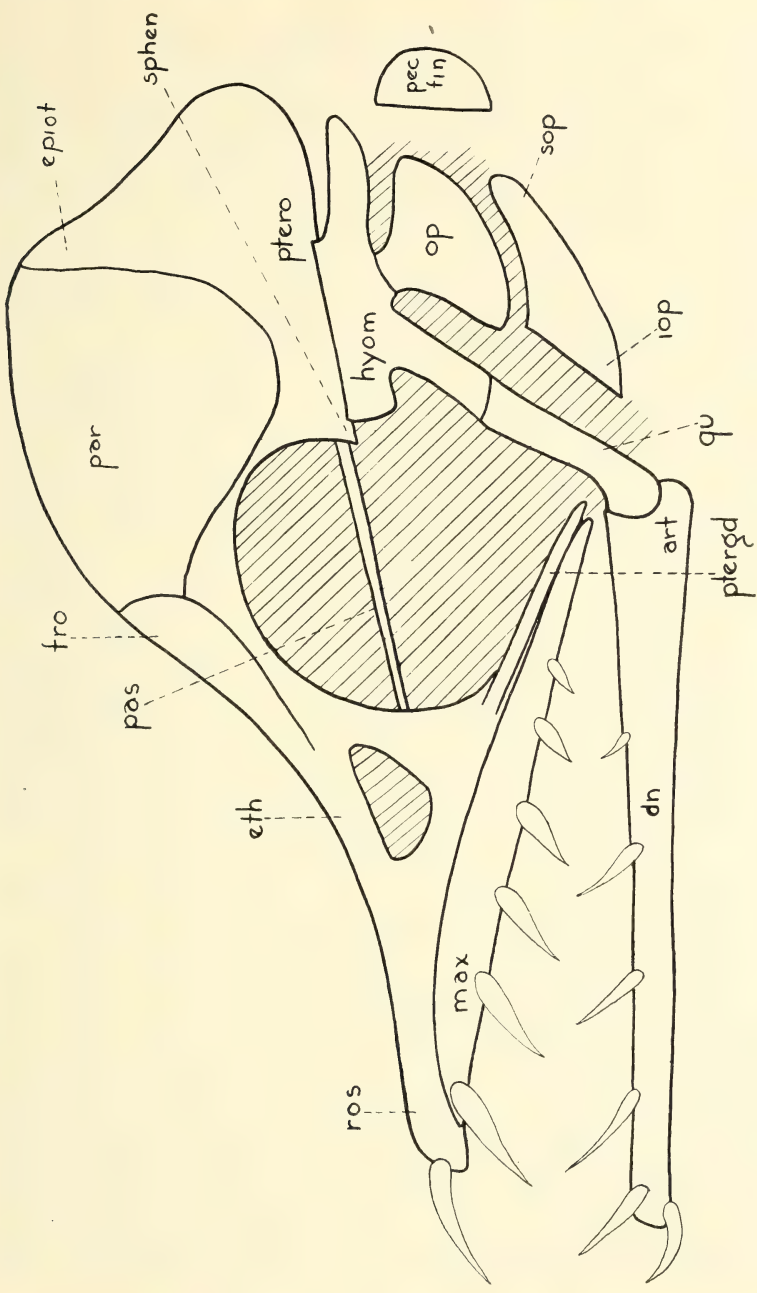
Fig. 27. *Serrivomer beanii.* Cartilaginous elements of larval head, lateral view. Standard length 36 mm. (x 44).

Jaw Apparatus: The vomer, or from its intimate connection, the ethmo-vomer, is the bearer of a single row of large palisaded teeth. These lessen in size anteriorly and posteriorly, and at the level of the end of the maxillary are replaced by an elongate area of minute irregular teeth, which occupy the whole of the tip of the upper jaw. (See p. 58 for detailed description of teeth). The maxillae are long and slender, occupying about three-fourths of the upper jaw, and are furnished with small, irregular teeth. The lower jaw, similarly armed, is deep and strong. No separate angular is distinguishable and the articular is relatively small, and posteriorly restricted.

Opercular Apparatus: The opercle is large and triangular, with its posterior point drawn out. The preopercle equals the former in size, forming a wing-like extension which actually overlies the elongate, bodkin-shaped interopercle. Curving around the antero-inferior angle of the opercle is the boomerang-shaped subopercle.

Hyoid Arch: The glossohyal in this eel is well developed and not especially slender, of equal calibre throughout. The urohyal is shield-shaped and curves down and back from its articulation. Of the paired elements of the hyoid apparatus, there are two linear bones, the hypohyal and the ceratohyal. The latter is twice the length of the former, and the two elements are perfectly distinct. Epihyal and interhyal are, however, indistinguishable. A second hypohyal lies outside the hyoid arch, a thin rod closely applied to the first hypohyal and the proximal half of the ceratohyal.

There are seven branchiostegals, of thread-like diameter, all very long and curved gradually upward, except for the first which is quite short. This short one arises from the distal end of the first hypohyal, all the rest springing from the ceratohyal. The first four are widened where they articulate with their supports and all six extend far forward beyond even the second hypohyal as free rods, apparently a regular character of this species. The seventh branchiostegal arises very close to its predecessor and does not extend beyond its ceratohyal support.

Branchial Apparatus: The branchial arches are all slender, but well ossified. There are two basibranchials, the second about one-fourth the length of the first. Two hypobranchials, short

and fairly stout, are developed, subequal in size.   All five cerato-branchials are found, the first four long and slender, the fifth strongly dentigerous and closely applied to the anterior face of the fourth.   Four epibranchials are followed by five pharyngo-branchials, the end of the fourth and all of the fifth being dentigerous and half the length of the opposed and toothed cerato-branchial.

Pectoral Girdle: The curving cleithrum is attached immediately beneath the junction of the eighth and ninth vertebrae. A third of its length from the top arises a small, oblong upper coracoid.   A much smaller lower one is ankylosed to its distal end, and supports seven pectoral rays. The longest ray is equal to the horizontal diameter of the eye. Radials are absent.

Vertical Fins and Supports: The dorsal fin commences at the vertical from the end of the 27th vertebra, opposite the 12th anal ray.   Throughout the length of the fin the rays are very short, never equalling more than half the depth of the body at their points of attachment; they are always shorter and more closely set than the corresponding anal rays.   The latter commence at the level of the end of the 21st vertebra.   The first dozen and the last 50 are set more closely together than the rest. The rays are longest in the second third of the fin's length, where they are fully three times as long as the corresponding dorsal rays, and equal the depth of the fish in that region. Most of the finrays of both fins have a flattened, expanded area somewhere near the middle of their lengths, and in the caudal region the rays become very short, flattened and wavy, though they are still strongly ossified.

There is a radial with expanded ends occupying the entire space between each two finrays of both fins. The anterior end of each radial is slightly lower than the posterior in the dorsal fin and higher than the posterior in the case of the anal.   A baseost is developed for every ray, all directed strongly backward.   In the anterior part of the anal fin, however, these elements lie almost parallel to the horizontal radials, out of the way of the coelomic organs, which continue behind the anus. Correlated with this is the absence of the haemal arch and spine in the same region (see below).

Vertebral Column: In the large, cleared specimen under
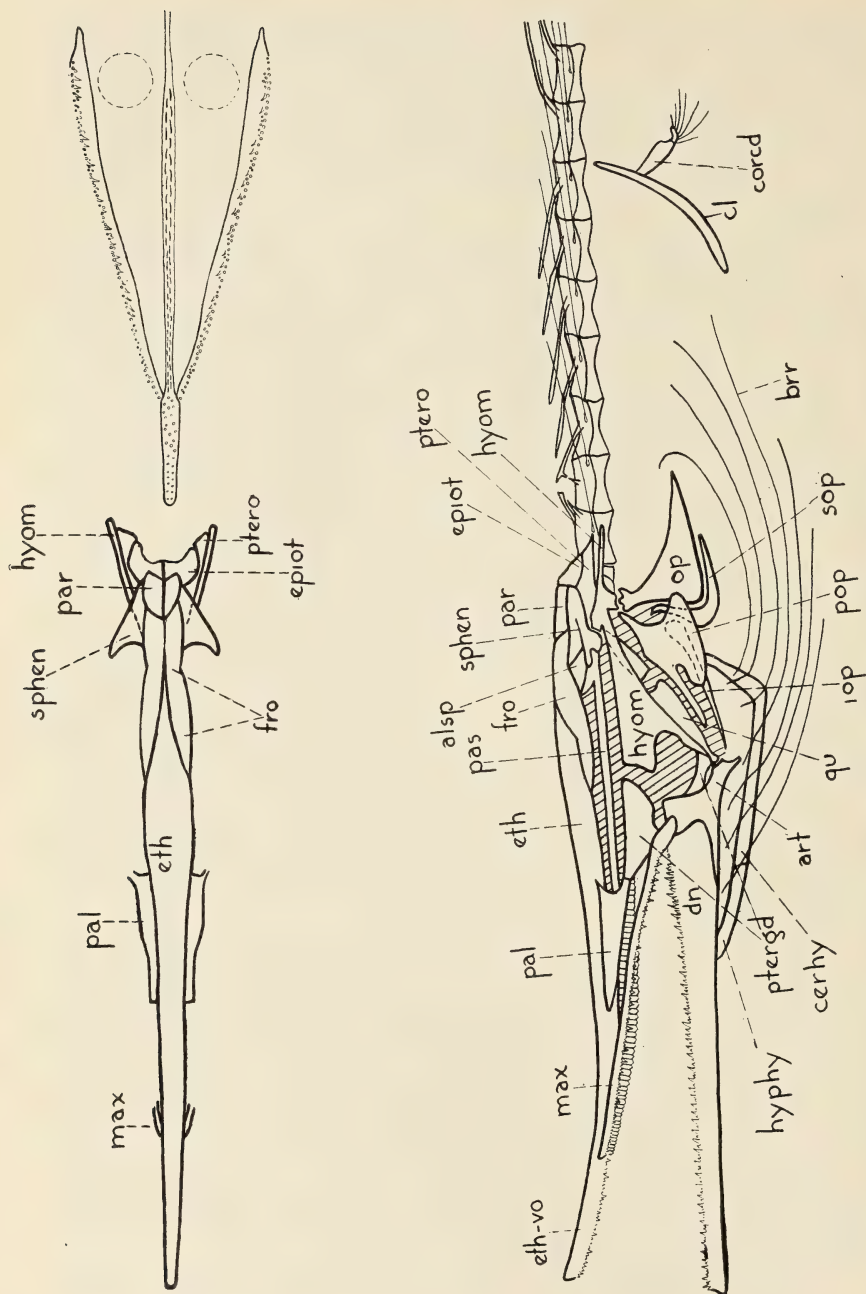
Fig. 28. (upper left). *Serrivomer beanii*. Skull of adult, dorsal view; standard length 440 mm. (x 10).
Fig. 29. (upper right). Same, teeth of upper jaw and vomer, ventral view. (x 10).
Fig. 30. (lower). Same, bones of head, pectoral girdle and anterior part of vertebral column, lateral view. (x 10).
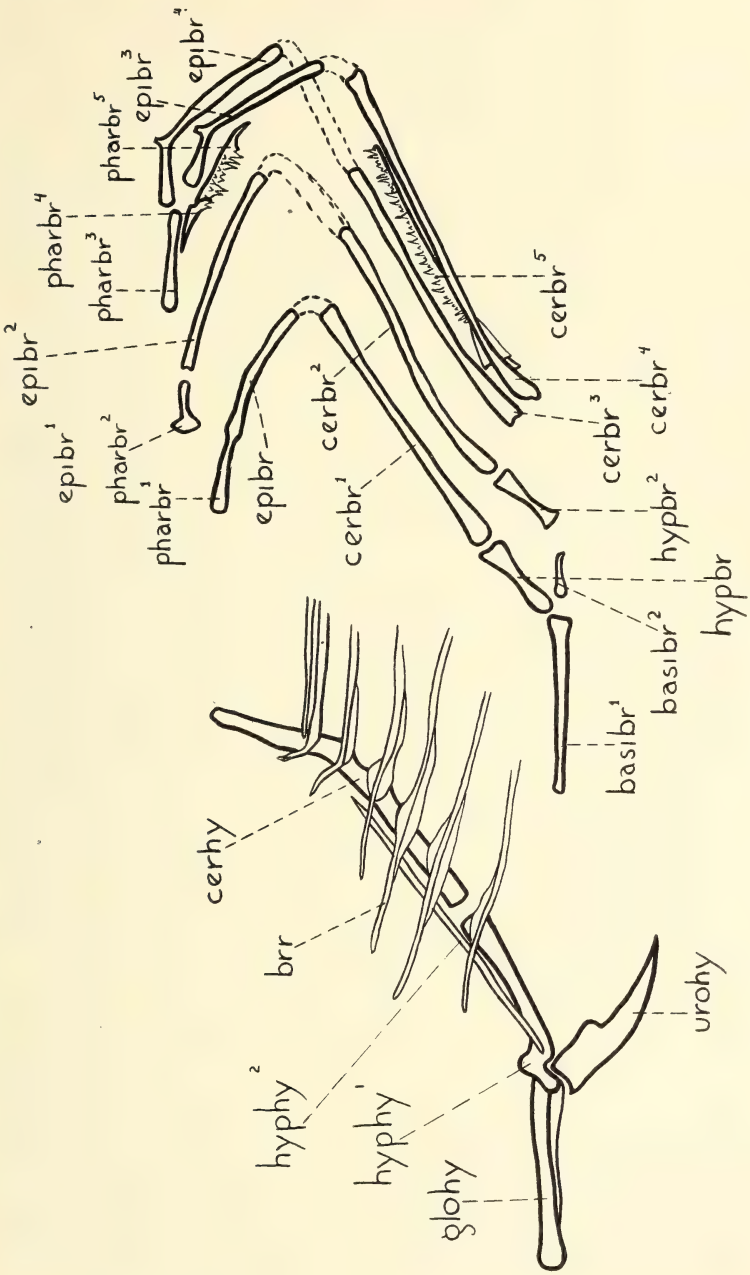
Fig. 31. *Serrivomer beanii.* Hyoid and branchial apparatus of adult, standard length 440 mm. (x 3.4).

stomach and ovaries
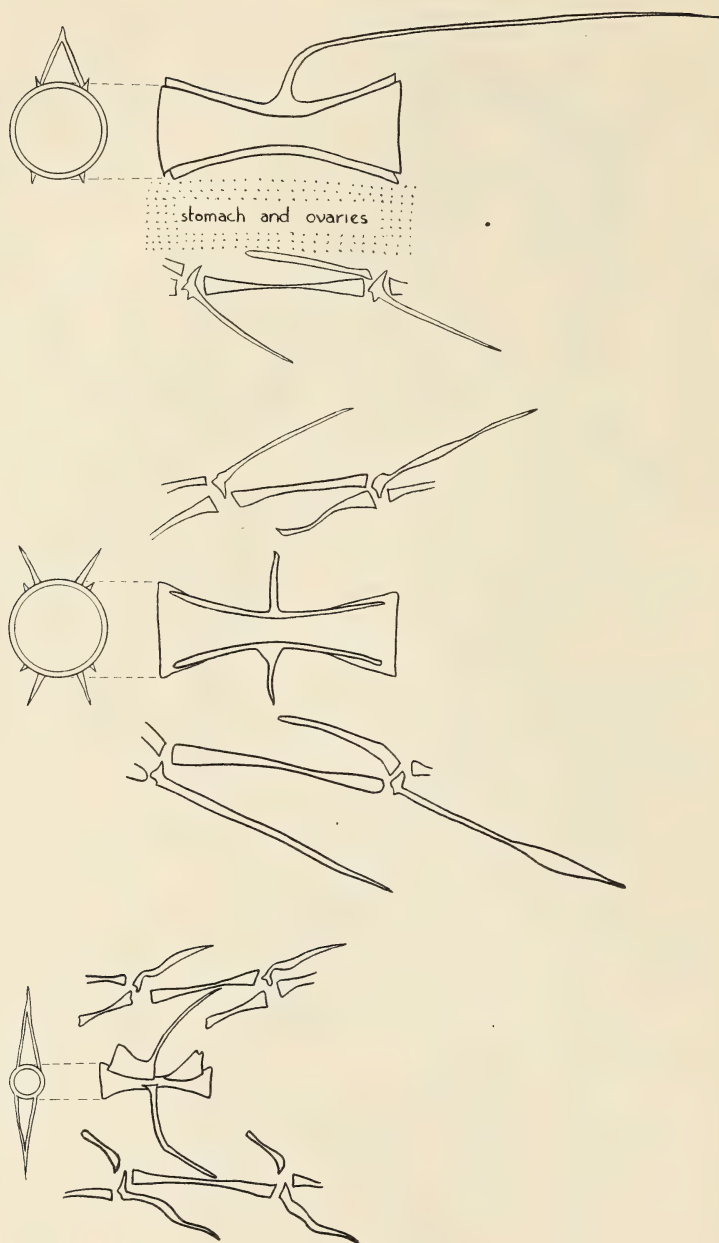
Fig. 32. *Serrivomer beanii.* Upper, 25th vertebra and 10th and 11th anal rays; middle, 97th vertebra; lower, 111th vertebra. (All x 9.3).

discussion there were about 160 vertebrae (the exact number indeterminable, as tail is missing). Excluding the atlas, which is only half the maximum size, and the second and third, which are slightly less than maximum, the centra remain of the same length as far back as about the 97th, or almost to the posterior fifth of the anal fin. From here backward there is a rapid reduction in size. The proportions remain about the same throughout, the maximum height of each centrum being about two-fifths of its length, and the minimum about one-tenth.

The pre-cleithral vertebrae—i.e. the first eight, counting the atlas—are furnished with very large neurapophyses, which more than equal the centra in height. Behind the girdle they decrease rapidly in size and throughout most of the length of the column are represented only by a pair of low ridges running almost the full length of each centrum just beneath its dorsal profile. Toward the end of the column, however—for about the last sixty vertebrae—each neurapophysis takes the form of a pair of wings, one in the front half, the other at the rear of the centrum and equal to the maximum height of the centrum.

The second vertebra (first behind atlas) has two dissimilar neural spines, posteriorly directed, near the posterior edge of the neurapophysis. On the third vertebra they are median, minute, nearly erect, and almost joined to form an arch. In the fourth the arch is complete and *anteriorly* directed, furnished distally with a short spine and a small antero-ventral projection which almost touches the pair of spines in the preceding vertebra. The four succeeding arches—of the fifth through the eighth vertebrae—are identical with that of the fourth, except that the spine is longer and there is no antero-ventral projection. The arch plus the spine in each case is half again as long as a vertebra. At the ninth vertebra the direction of arch and spine is abruptly reversed, extending obliquely backward instead of forward. The arches become shorter and the spines increase in relative length, reaching their maximum close behind the anus, before the dorsal origin. Here the arch—vertical, nearly median, and fairly short—gives rise to a spine which is almost twice as long as the centrum and lies almost horizontally. From here backward the spine is gradually reduced in size and vanishes at about the 38th vertebra, the arch once more opening at the top

to form a pair of spines, as in the second and third vertebrae. In the most posterior part of the column, at about the 107th vertebra, the arch is again completed, its apex almost touching the dorsal baseost, and sends a short spine backward. Each of the first 17 neural arches is strengthened by a cross bar placed across the arch well below the apex.

Epineurals are distinguishable only on the first eleven vertebrae after the atlas. These are well ossified and there is no sign of epipleurals or of ribs anywhere along the column.

In the anterior part of the column haemapophyses correspond exactly to the neurapophyses, taking the form of narrow ridges close to the ventral profiles of the centra.

The first, incomplete, haemal arch—in the form of a pair of median, vertical spines—does not appear until the 91st vertebra, the 70th behind the anus. This is obviously connected with the post-anal extension of the coelomic organs. Similar structures are present on the 92nd, lacking on the 93rd and 94th, present on the 95th, lacking on the 96th, and present on all subsequent vertebrae. The first complete haemal arch appears on the 107th vertebra, the apex of the arch almost touching the anal baseost. Small, backwardly directed spines arise from the arches of subsequent vertebrae.

End of Vertebral Column and Caudal Fin: The caudalwards alteration of the vertebrae is so slow and gradual that it is difficult to say where it begins. The fourth from the urostyle is very spool-like in lateral view, and shows a large, rounded neural arch, topped with a short, irregularly backward directed spine. The haemal arch is smaller with a correspondingly larger and longer spine. The next three vertebrae are slightly smaller, but have actually larger arches. In the ultimate vertebrae the neural arch is slightly open, but the haemal is closed.

Although all the succeeding elements are fused, yet what we must call the proximal part of the urostyle is intrinsically a very distorted but entire vertebra. The widely separated arms of the neural element wave irregularly in midair, and what was a large, lateral foramen in the haemal arch of the preceding vertebra has become enlarged and has broken the haemal arch apart into two pairs of slender, bent processes. Posteriorly there is a short, ventral pair of spines and the dorsal aspect is drawn
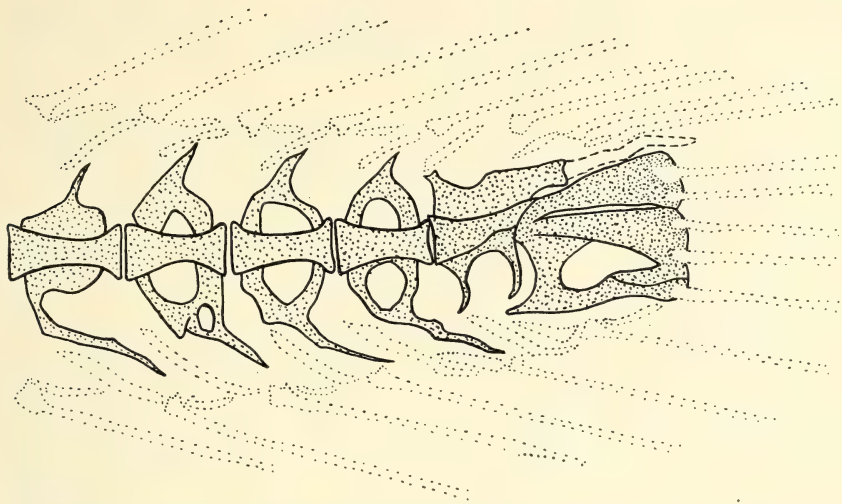
Fig. 33. *Serrivomer beanii*. Posterior part of vertebral column and base of caudal fin in adult female, standard length 405 mm. (x 43).

out into a long, slender projection, longer than the whole main body. This supports a well developed extension of neural arch, completely sheathing the spinal chord. About half way to the end of the vertebral spine, this arch ends, and the naked chord continues to the base of the caudal rays, then bends rather abruptly upward, over the dorsalmost ray and actually out some distance beyond the rounded homogeneous, cartilaginous caudal plate.

The most dorsal, or first, hypural arises at the posterior opening of the urostyle vertebra, extends backwards as a fairly stout rod, and supports two caudal rays. The second hypural at its base is indistinguishable from the first, but soon separates and parallels it to the caudal tip where it, too, supports two rays. The third hypural instead of as usual arising from the separate, antepenult vertebra, originates in the same cartilaginous mass as the two other hypurals. It extends downward and then backward, leaving a large, rounded foramen along its dorsal border. From its end arises the final or fifth caudal ray.

COELOMIC ORGANS: Stomach extending slightly behind anus, black; intestine straight; caeca absent; kidney spotted throughout, ending above anus, suspended below anterior part

of gonads; gonads beginning at perpendicular of origin of stomach, extending almost as far behind anus as anus is from tip of snout.

DEVELOPMENT

MATERIAL: All stages are represented in the collection, although transitional adolescents predominate:

Larvae, 17 to 63 mm.: 15 specimens.
Post-larvae, 54, 59 mm.: 2 specimens.
Adolescents, 61, 90 mm.: 2 specimens.
Transitional Adolescents, 90 to 318 mm.: 133 specimens.
Adults, 400 to 440 mm.: 3 specimens.
Total: 155 specimens.

The division between transitional adolescents and adults is unavoidably arbitrary, as none of our specimens is in breeding condition, and it is unknown whether or not these deep-sea eels breed more than once. In view of the fact that eggs when distinguishable, are all of a size, it seems probable that each individual spawns but a single time. Of the three specimens over 400 mm., it is not likely that any has eggs far enough developed to be deposited the same year. If this is the case, we have of course no fully adult specimens. Nevertheless, it has been found practicable to set off these three much larger and more fully ossified specimens from transitional adolescents. Sex is unquestionably determinable in about 18 specimens, all measuring over 200 mm.; these are without exception females.

KEY TO THE GROWTH STAGES:

A. Body more or less flattened laterally, its height much greater than its thickness and contained not more than 20 times in the length; translucent.
    B.   Depth in length 7.8 to 10; vertical fins incomplete; no general pigment.
        C.   Larval fangs present; anal origin between 89th and 97th myomere ....*Larva* ("Leptocephalus")
        CC. Larval fangs absent; anal origin between 80th and 25th myomere ....*Post-larva* ("Tilurid A")

BB. Depth in length 15 to 20; vertical fins complete (anal
    origin about 20th myomere); pigment appearing.
                               Adolescent ("Tilurid B")

AA. Body rounded; slender (depth in length 30 to 80); opaque.
    D.   Gonads developing; pigmentation, ossification and den-
        tition immature in earlier half of stage.........................
                         Transitional Adolescent
    DD. Specimens ready for breeding...............................*Adult*

BRIEF SUMMARY OF CHANGES OCCURRING DURING GROWTH[2]:
Although the larval stage of *Serrivomer,* as in all eels, is so ex-
ceedingly unlike the adult in appearance, and unlike the larvae
of other fish both in appearance and in persistence of the stage,
yet in all salient points the leptocephalus is a typical larva, with
gut pendulous, finfolds present, eye vertically elongate, and the
alimentary canal a simple tube. But in two particulars it con-
trasts strongly with the larvae of other fish: first, the body is
compressed to more than flounder-like thinness and is corre-
spondingly deep; and, second, the larval stage persists until the
fish has reached a length of 55 or 65 mm. (in the present genus;
much more in some other eels), instead of having this period
confined to, say, a maximum of 10 mm. of length.

Following this unusual larval stage, however, development
is typical of an elongate deep-sea fish, such as a stomiatoid.
There is a hasty transformation, during which the most blatant
larval characters are swiftly modified into the general appear-
ance of those of the adult: the body becomes rounded and slen-
der, the head is lengthened (contrary to stomiatoid development,
where the head is reduced during this early stage), the eye is
reduced in size and horizontally instead of vertically elongate,
the jaws attenuated, and the fins assume their adult positions—
the dorsal and anal actually moving forward along the profiles
from their previous cramped location posteriorly, exactly as in
the isospondylous *Idiacanthus.* Also the usual brief period of al-
most complete toothlessness is present, and pigment develops
from adolescence onward. As in other fish, this transformation
takes place during the post-larval period and that of early

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2 Detailed descriptions beginning on p. 82. See also table, p. 87.

adolescence. During this time growth almost ceases and an actual shrinkage of a few millimeters—not more in this species—probably takes place. Growth is resumed in late adolescence, when the body is losing the last traces of its leptocephalid compression. This period merges into the usual long, transitional adolescence of growth and osteological and gynecological development, commencing when the fish reaches about 90 mm. *Serrivomer*, with its slowly grown teeth and digestive organs, resembles the isospondylous stomiatoids much more closely than it does the digestively precocious *Omosudis* of the Iniomi. The extreme forward development of the snout is, of course, unique, as is the tardily appearing vomerine ridge, which is practically indistinguishable until transitional adolescence, and yet is the distinguishing mark of the genus.

Diagnostic Description of Growth Stages:

Larva: (Figs. 24, A to E incl.; 25, A to E incl.)—Pigment: This is found in two or three areas, the first two present throughout the larval stage, the third tending to disappear in older larvae: 1. An irregular series immediately below the midline, outlining the myomeres, usually several chromatophores to each myomere where they occur, but they are not present on every myomere. Pigment is especially scanty anteriorly; it may even be completely lacking in the anterior two-fifths of the fish. 2. A series of fine dots along the base of the anal fin. 3. A series of 6 larger spots, 3 above and 3 below the tip of the caudal. These usually vanish when the fish reaches a length of 35 or 45 mm..

Proportions: Depth (measured to exclude intestine and finfolds) moderate, 7.1 to 9.6 in length (10.4% to 13%). Head in length 8.5 to 4.2 (7% to 11.7%), largest in youngest specimens. Eye 38 to 84 in length (2.6% to 1.2%), decreasing in relative size with growth, vertically elongate in young specimens, becoming rounded in the older ones. Snout long, slender, almost or more than equal to distance from posterior margin of eye to pectoral origin; outline at first extremely concave while supraorbital distance is greater than the horizontal diameter of the eye; with growth, the snout loses most of its concavity and the supraorbital distance becomes much reduced, the highest

point of the head eventually falling well behind the eye; lower
jaw slightly projecting; jaw angle under posterior margin of
eye in young specimens, distinctly behind it in old; this is due,
however, to the relatively decreased size of the eye, not to a
relative increase in the length of the jaw.

Teeth: A pair of long, curved, fang-like larval teeth at tip
of both jaws, each tooth followed by from five to eleven slightly
smaller, less curved teeth. All of the teeth arise from the outer
sides of the jaw cartilages, not from their margins; in the oldest
fish, due perhaps to consolidation of the jaw margins, the teeth
are closer to the rim than in the younger specimens. In these
larger ones, too, the upper teeth are in two groups, the posterior
three to five being much smaller than the others. The teeth in-
crease in number until the fish reaches a length of about 35
mm.; just before transformation commences they drop out, un-
til only several are left in each jaw in a transitional specimen
of 57 mm.

Fins: Pectoral large, fan-like, without true rays, base en-
larged, typically larvoid, becoming reduced in size with growth
of fish; anal short, occupying last one-sixth to one-fourth of fish;
dorsal considerably longer (up to half again as long) ; rays of
both fins undeveloped in smallest specimen; tail and surround-
ing fin distinctly pointed even in smallest; dorsal finfold per-
sisting throughout the larval stage, from the nape backwards,
the finrays elevated upon it; anal finfold similar but starting
considerably behind pectoral fin.

Osteology: Figs. 26 and 27 depict the cartilaginous struc-
ture of the larval head. At this time, remark will only be made
of the complete absence of a supraoccipital, its lack being an
important family character.

Coelomic Organs: The alimentary canal bends sharply
downward immediately behind the heart and from there back-
wards is depended from the myomeral body only by delicate
membranes and ligaments. Anlagen of the stomach and other
digestive organs are distinguishable in the older larvae. The
kidney is clearly visible and ends at about the 30th myomere,
the urethra proceeding from here to the anus. Gonad rudiments
indistinguishable.

Myomeral Count: 154 to 165 myomeres, 89 to 97 in front of

anus (89 in smallest specimen; others with 93 to 97).

Shrinking: As the largest larva (63 mm.) has all its teeth intact, while one of only 57 mm. shows but several in each jaw, it is likely that a shrinkage of several millimetres takes place immediately preceding metamorphosis.

Post-larva: (Figs. 24 F, 25 F). During the post-larval and adolescent stages the actual transformation from leptocephalous to anguilliform takes place: the post-larva differs from the larva most obviously in the loss of larval teeth and in the forward migration of the vertical fins, with a corresponding shortening of the intestine and urethra; the depth gradually decreases to almost half that of the larva, while the body becomes slightly but noticeably thickened. The only traces of larval pigment are a few dots scattered along the anal fin; otherwise the fish is completely colorless. The head is in form midway between that of larva and adult: it is relatively longer; all of its parts are lower and the eye smaller than in the larva, the jaws having partially assumed their characteristic slenderness; the larval teeth have entirely disappeared, but very rudimentary permanent teeth are appearing as minute nodules in several rows on maxillary, mandible and vomer. The pectoral has become further reduced and true rays are forming. The dorsal and anal fins move forward very rapidly although actual growth has practically ceased, and in the most advanced post-larvae these vertical fins occupy almost their final positions. In the younger of our two post-larvae (54 mm.) the anus is at the eighty-third myomere, a forward migration of about 14 myomeres since the larval stage; in the older (59 mm.) the anus falls still farther forward, at the seventy-first. Traces only of finfold remain, but the dorsal and anal are still noticeably elevated. The end of the caudal peduncle is abruptly attenuated. The gut is still pendulous, but lies close against the myomeral body. There is no trace of ossification. The post-larval skull differs from that of the larva principally in the reduction in its height and in the extension of the postorbital and opercular regions. Except for the change in dentition, the jaws show relatively little modification.

Adolescent: (Figs. 24 G, H and 25 G, H). In the adolescent the form is semi-leptocephaloid, i.e. there is no mistaking the

identity of the fish at a glance, but the body is distinctly flattened and though more slender than in the post-larva is still at least twice as deep as in the adult. Pigment is developing, spreading from the ventral portion of the fish upward, but the end of the tail portion is quite colorless; traces of several larval pigment spots may remain at the base of the anal. The head is almost of adult aspect, relatively larger and lower, the eye decreased nearly to adult proportional size and laterally elongate. The teeth are developing, but those of the vomer are still in several rows throughout, with the future vomerine ridge practically indistinguishable. All five nostrils are evident. The fins are complete, the anus falling at about the twenty-second myomere. Neither dorsal nor anal is any longer elevated on finfolds, but arises directly from the myomeral body. All trace of finfolds is absent. The intestine is completely enclosed. The viscera of the adult are all plain—stomach, pylorus, intestine, liver (very rudimentary), kidney, urethra and thread-like gonads—and all are in their final positions. The stomach barely reaches the level of the anus, however, and is scarcely pigmented. There is no ossification.

Transitional Adolescent: (Figs. 24 I, 25 I). As in most fishes the transitional adolescence is a long period of growth previous to arrival at full breeding condition. As in all eels, however, the changes remaining to be made following adolescence are greater than usual, probably because of the great extent of the metamorphosis, though they differ only in degree from the majority, not in kind. In the early part of the stage the body is at its roundest —even more so than in the full adult, where it becomes secondarily comparatively flattened in the caudal region; pigment develops steadily as well as a characteristic, iridescent, silver, outer coat (fragile and almost absent in a number of specimens). The head remains of the same proportions as in the adolescent, although the body cavity becomes relatively shorter due to the increased length of the caudal peduncle, and the postorbital region develops at the expense of the snout. The teeth attain their full development very late. This is especially true of those on the vomer, as this bone retains extra, small, irregular teeth on each side of the vomerine ridge until the fish has reached a length of about 150 mm. The extra teeth disappear from the posterior

part of the vomer forward, the vomerine ridge becoming correspondingly pronounced and high.

In a specimen of 132 mm. the teeth, jaws, ethmo-vomer, hyomandibular and hyoid arch show moderate ossification; the brain-case, first dozen vertebrae, opercles and pectoral girdle a slight amount; and the remainder of the vertebral column, the branchial apparatus, finrays and their supports, and the tail none whatever. In a 250 mm. specimen all of the ossification is much stronger, and only the vertical fins, their supports and the end of the vertebral column are feebly or not at all stained.

The stomach becomes gradually black during this stage and is extended slightly beyond the anus. Sex can be determined in fishes of 200 mm. and over, but the gonads are minute.

RELATIVE PROPORTIONS DURING GROWTH: The table on page 87 shows the change of proportions and appearance of teeth during the development of *Serrivomer beanii*.

ECOLOGY

SEASONAL DISTRIBUTION: Both actually and theoretically *Serrivomer beanii* is most numerous during mid-summer, although it is fairly common throughout the trawling season. The youngest larvae—i.e., several under 30 mm. in length—were taken in June and July, making it probable that at least some spawning takes place in late spring or early summer. Larger larvae, however, were caught straight through from May to September. Successive stages show no correlation with the seasons. (See Table A and B, page 88).

VERTICAL DISTRIBUTION: *Serrivomer beanii* was taken between 50 and 1,000 fathoms, at a mean depth of 606 fathoms. When this average is computed on the theoretical basis of an equal number of nets drawn at each level, however, the mean is brought up to 485 fathoms, as *Serrivomer* was very common in the comparatively few nets drawn above 500 fathoms. Only two specimens, both larvae, were captured above 200 fathoms, but the average depth (727 fathoms) at which all larvae were caught is deeper even than the mean of the transitional adolescents and adults (594 fathoms). The question of the number of these leptocephali which entered the nets on their way to the surface

Growth Stage	Length (mm.)	Pre-anal Myomeres	Post-anal Myomeres	Maximum Depth: Length %	Head: Length %	Eye: Length %	Snout: Length %	Snout-to-Dorsal: Length %	Snout-to-Anal: Length %	Maxillary Teeth	Mandibular Teeth
Larva	17	89	69	12.5	11.7	2.6	5.1	-	83	4	5
Larva	25	96	60	13						9	7
Larva	34	95	?	12.8	9	2	4	73	83	8	7
Larva	34	93	61	12.6						11	9
Larva	36	97	63	12						10	8
Larva	42	95	70	11.6	7.8	1.7	3.5	76	83	9	9
Larva	43	96	64	11.2						11	9
Larva	46	97	65	10.9						12	10
Larva	46	97	62	10.4	7.2	1.4	3.3	76	76	12	9
Larva	49	96	69	13						13	11
Larva	52	94?	?	12						10	9
Larva	56	94	62	11.8	7	1.2	2.5	72	79	10	8
Larva	63	94	69	12.6						12	11
Transitional Larva	57	97	66	10.6	8	1.2	3.2	69	78	4	1
Post-larva	59	71	97	11.4	7.4	1.3	3	57	60	True teeth appearing	
Adolescent	90	22	?	2.4	16	.7	7.8	29	23	True teeth appearing	
Transitional Adolescent	214	22	?	1.4	15.5	.6	6.7	29	23	Teeth almost complete	
Adult	440	22	?	3.2	16.6	.8	6.5	31	26	Teeth complete	

is in this case especially important: according to the probability averages, not more than a third of those caught in deep-level nets were caught on the way up. Both small and large larvae were taken at high and low levels. (See Table C). No correlation is shown between depth and season.

Table A. Relation of Growth Stage to Season

	April	May	June	July	Aug.	Sept.	Oct.	Total
Larvae	..	1	5	2	2	5	..	15
Post-larvae	..	..	..	1	..	1	..	2
Adolescent	1	..	1	..	..	..	..	2
Trans. Adolescent	9	30	34	30	13	16	1	133
Adult	..	..	1	..	..	2	..	3
Total	10	31	41	33	15	24	1	155
Theoretical total[3]	68	58	57	49	27	24	26	

Table B. Length of Larvae in Relation to Season

Length	May	June	July	Aug.	Sept.	Total
17-25 mm.	..	..	2	..	..	2
26-35 mm.	1	1	..	..	1	3
36-45 mm.	..	1	..	1	1	3
46-55 mm.	..	1	..	1	2	4
56-63 mm.	..	2	..	..	1	3
Total	1	5	2	2	5	15

Table C.

Growth Stage	Average Depth
Larvae	727 F.
Post-larvae	600 F.
Adolescents	550 F.
Transitional Adolescents	589 F.
Adults	800 F.

If the two-foot *Serrivomer*-like fish observed from the Bathysphere between 125 and 250 fathoms actually belonged to this most abundant species, it is evident that the upper level of the swimming range of the adults lies far above that at which they are caught in the nets. In the latter only one small transitional adolescent (140 mm.) was taken as high as 200 fathoms; no specimen of 400 mm. and over was taken above 700 fathoms.

ABUNDANCE: *Serrivomer beanii* is fairly common among the deep-sea fishes of Bermuda, and is taken only slightly more

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[3] Computed on basis of the same number of nets being drawn every month as during September. See ZOOLOGICA, Vol. XVI, No. 1, p. 7.

often than other numerically comparable forms, such as *Idia-canthus fasciola*, *Bathytroctes rostratus*, *Bathylagus glacialis* and *Omosudis lowii*. It is far and away the most successful of the deep-sea eels in this locality, its nearest numerical rival in the collection being *Gastrostomus*, of which about 85 specimens have been taken by the Bermuda expeditions (*Serrivomer beanii*: 155 specimens).

SOCIABILITY: Judging from the evidence of both Bathy-sphere observations and trawling records, *Serrivomer* swims both alone and in company with several other fish of about the same stage of development. In the great majority of nets in which it was taken, *Serrivomer* was solitary, but in 12 per cent. (sixteen) from two to five specimens came up together. In all but two of these cases the fish were transitional adolescents. One of these exceptional nets held two larvae, the other a larva and a transitional adolescent.

FOOD: *Serrivomer* is primarily an eater of fairly large shrimps and euphausiids, although fish of equal size and small crustaceans are occasionally found in the stomachs.

Roule (1934) has developed in detail the theory that deep-sea fishes which seek relatively large prey undergo long rest-ing periods between meals, as the majority of his specimens have proved to have empty stomachs. If this supposition is correct, *Serrivomer* would doubtless be included in the group: The stom-achs and intestines of more than 135 transitional adolescents and adults of the present collection were examined, but only 23 or about 16 per cent contained more than the faintest trace of food. Roule draws his principal analogy, however, from the habits of the great snakes on land—reptiles which actually re-main quiescent during the "resting period." Judging both from the Bathysphere observations and from rationalization, however, quiescence is impossible in the mid-depths of the ocean, where it seems that the fish must maintain a certain degree of activity all of the time. Judging again from Bathysphere observations, "game" is plentiful, so that in the case of active fish at least, long abstinence is unnecessary. Still again, some fish with the greatest stomach capacity (e.g., *Omosudis* and *Chiasmodon*) are very rarely taken *without* abundant food. And finally, plank-

ton feeders, such as *Cyclothone* and most young fish—which, as Roule says, have a continuous supply of nourishment—are taken with empty stomachs almost as often as are the large predaceous forms. Therefore Roule's conclusion seems very questionable; the answer to the puzzle is probably that digestion takes place with extreme rapidity, at least immediately before and after death, the process being perhaps stimulated by capture.

The food was distributed among the 23 Bermuda specimens as follows:

Stomachs with shrimps or euphausiids.............................. 19
Stomach with copepods and *Phronima*-like hyperid...... 1
Stomach with 70-mm. myctophid..................................... 1
Stomach with *Cyclothone signata*.................................... 1
Stomach with *Cyclothone microdon*................................. 1

Those of the shrimps which were fairly well preserved were all *Pasiphaea*-like; it is likely that all were either of the same kind or very closely related. None of the remains was definitely euphausian, but it was impossible to refer the poorly preserved material definitely to shrimps. The fish and shrimps were all large compared with the *Serrivomer,* each completely filling, but not greatly distending, a stomach.

In the larval intestines remains of radiolarians were found.

ENEMIES: *Serrivomer* has not been found inside of any animal.

VIABILITY: No Bermuda *Serrivomer* has been brought up alive. The only record I know of one of these eels being seen alive is a *Serrivomer sector* which was caught at 500 fathoms well up in the Gulf of California halfway between Guaymas and Santa Inez Bay. This was on April 8, 1936, at Station 139 T-4 of the Zoological Society's Templeton Crocker Expedition. The eel was a large one, measuring 580 mm. (22 in.) in length. It was very active and lived for more than an hour, snapping at my fingers and swimming with equal ease backward and forward in its aquarium. The iridescent, silvery epidermis was very noticeable.

HABITAT OBSERVATIONS:

STUDY MATERIAL

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of each specimen of *Serrivomer beanii* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in ZOOLOGICA, Vol. XVI, No. 1, p. 5, and Vol. XX, No. 1, p. 1. "Trans. Adol." stands for "Transitional Adolescent."

No. 9,548; Net 32; 600 F.; April 24, 1929; 138 mm.; Trans. Adol.
No. 9,567; Net 34; 700 F.; April 24, 1929; 96, 106, 134 mm.; Trans. Adol.
No. 9,705; Net 36; 900 F.; April 24, 1929; 318 mm.; Trans. Adol.
No. 9,597; Net 39; 600 F.; April 25, 1929; 114 mm.; Trans. Adol.
No. 9,652; Net 41; 600 F.; April 25, 1929; 90 mm.; Adolescent
No. 9,697; Net 45; 500 F.; April 25, 1929; 144 mm.; Trans. Adol.
No. 9,656; Net 46; 600 F.; April 29, 1929; 127 mm.; Trans. Adol.
No. 9,648; Net 47; 600 F.; April 29, 1929; 98 mm.; Trans. Adol.
No. 9,878; Net 89; 600 F.; May 10, 1929; 120 mm.; Trans. Adol.
No. 9,928; Net 98; 400 F.; May 14, 1929; 115, 115 mm.; Trans. Adol.
No. 9,954; Net 101; 700 F.; May 14, 1929; 119 mm.; Trans. Adol.
No. 9,955; Net 102; 800 F.; May 14, 1929; 115 mm.; Trans. Adol.
No. 9,985; Net 111; 700 F.; May 16, 1929; 133 mm.; Trans. Adol.
No. 10,123; Net 118; 900 F.; May 18, 1929; 102 mm.; Trans. Adol.
No. 10,138; Net 123; 800 F.; May 25, 1929; 110 mm.; Trans. Adol.
No. 10,152; Net 124; 900 F.; May 25, 1929; 34, 132 mm.; Larva, Trans. Adol
No. 10,175; Net 129; 400 F.; May 27, 1929; 105 mm.; Trans. Adol.
No. 10,183; Net 130; 500 F.; May 27, 1929; 142 mm.; Trans. Adol.
No. 10,319; Net 147; 600 F.; June 1, 1929; 135 mm.; Trans. Adol.
No. 10,350; Net 157; 1,000 F.; June 8, 1929; 120, 132 mm.; Trans. Adol.
No. 10,375; Net 158; 500 F.; June 12, 1929; 138, 141 mm.; Trans. Adol.
No. 10,420; Net 169; 1,000 F.; June 14, 1929; 115, 119 mm.; Trans. Adol.
No. 10,467; Net 170; 500 F.; June 15, 1929; 132 mm.; Trans. Adol.
No. 10,464; Net 174; 900 F.; June 15, 1929; 110 mm.; Trans. Adol.
No. 10,562; Net 184; 700 F.; June 18, 1929; 154 mm.; Trans. Adol.
No. 10,558; Net 185; 900 F.; June 18, 1929; 52, 56 mm.; Larvae
No. 10,559; Net 186; 1,000 F.; June 18, 1929; 42 mm.; Larva
No. 10,596; Net 187; 500 F.; June 19, 1929; 122, 136 mm.; Trans. Adol.
No. 10,683; Net 193; 500 F.; June 20, 1929; 125 mm.; Trans. Adol.
No. 10,753; Net 199; 500 F.; June 21, 1929; 110 mm.; Trans. Adol.
No. 10,754; Net 200; 600 F.; June 21, 1929; 160 mm.; Trans. Adol.
No. 10,757; Net 201; 700 F.; June 21, 1929; 123 mm.; Trans. Adol.
No. 10,755; Net 202; 800 F.; June 21, 1929; 142 mm.; Trans. Adol.
No. 10,875; Net 212; 600 F.; June 24, 1929; 144 mm.; Trans. Adol.
No. 10,876; Net 215; 900 F.; June 24, 1929; 63 mm.; Larva
No. 10,941; Net 217; 500 F.; June 25, 1929; 137 mm.; Trans. Adol.
No. 11,077; Net 233; 600 F.; June 28, 1929; 120 mm.; Trans. Adol.
No. 11,119; Net 240; 700 F.; June 29, 1929; 130 mm.; Trans. Adol.
No. 11,120; Net 241; 800 F.; June 29, 1929; 157 mm.; Trans. Adol.
No. 11,262; Net 254; 500 F.; July 5, 1929; 119 mm.; Trans. Adol.
No. 11,366; Net 271; 1,000 F.; July 8, 1929; 146 mm.; Trans. Adol.
No. 11,444; Net 279; 600 F.; July 10, 1929; 59 mm.; Post-larva
No. 11,705; Net 312; 700 F.; July 22, 1929; 154 mm.; Trans. Adol.
No. 11,913; Net 335; 700 F.; July 29, 1929; 140 mm.; Trans. Adol.
No. 11,984; Net 345; 500 F.; July 31, 1929; 25 mm.; Larva
No. 12,107; Net 355; 600 F.; Aug. 8, 1929; 123, 152, 162 mm.; Trans. Adol.

No. 12,167; Net 361; 500 F.; Aug. 10, 1929; 128, 129 mm.; Trans. Adol.
No. 12,174; Net 363; 1,000 F.; Aug. 10, 1929; 43 mm.; Larva
No. 12,284; Net 368; 700 F.; Aug. 14, 1929; 150 mm.; Trans. Adol.
No. 12,283; Net 371; 1,000 F.; Aug. 14, 1929; 200 mm.; Trans. Adol.
No. 12,500; Net 388; 900 F.; Aug. 17, 1929; 228 mm.; Trans. Adol.
No. 12,827; Net 399; 900 F.; Aug. 31, 1929; 49 mm.; Larva
No. 13,036; Net 416; 500 F.; Sept. 4, 1929; 138 mm.; Trans. Adol.
No. 13,073; Net 420; 900 F.; Sept. 4, 1929; 46 mm.; Larva
No. 13,134; Net 428; 1,000 F.; Sept. 5, 1929; 405 mm.; Adult
No. 13,163; Net 431; 600 F.; Sept. 6, 1929; 54 mm.; Post-larva
No. 13,237; Net 442; 1,000 F.; Sept. 7, 1929; 151 mm.; Trans. Adol.
No. 13,380; Net 453; 600 F.; Sept. 10, 1929; 123 mm.; Trans. Adol.
No. 14,418; Net 459; 400 F.; Sept. 12, 1929; 149 mm.; Trans. Adol.
No. 14,741; Net 539; 600 F.; May 6, 1930; 111, 133 mm.; Trans. Adol.
No. 14,779; Net 546; 1,000 F.; May 7 1930; 119 mm.; Trans. Adol.
No. 14,871; Net 562; 500 F.; May 10, 1930; 122 mm.; Trans. Adol.
No. 14,844; Net 563; 600 F.; May 10, 1930; 117 mm.; Trans. Adol.
No. 14,886; Net 567; 700 F.; May 12, 1930; 126 mm.; Trans. Adol.
No. 14,967; Net 573; 400 F.; May 14, 1930; 182 mm.; Trans. Adol.
No. 15,030; Net 580; 400 F.; May 15, 1930; 150 mm.; Trans. Adol.
No. 15,002; Net 583; 700 F.; May 15, 1930; 167 mm.; Trans. Adol.
No. 15,040; Net 587; 500 F.; May 17, 1930; 127 mm.; Trans. Adol.
No. 15,056; Net 588; 600 F.; May 17, 1930; 132 mm.; Trans. Adol.
No. 15,101; Net 594; 400 F.; May 19, 1930; 125 mm.; Trans. Adol.
No. 15,132; Net 595; 500 F.; May 19, 1930; 130 mm.; Trans. Adol.
No. 15,160; Net 604; 400 F.; May 20, 1930; 140 mm.; Trans. Adol.
No. 15,283; Net 619; 500 F.; May 22, 1930; 126 mm.; Trans. Adol.
No. 15,341; Net 626; 500 F.; May 23, 1930; 115 mm.; Trans. Adol.
No. 15,403; Net 631; 400 F.; May 26, 1930; 132 mm.; Trans. Adol.
No. 15,470; Net 637; 500 F.; May 28, 1930; 119 mm.; Trans. Adol.
No. 15,458; Net 639; 700 F.; May 28, 1930; 250 mm.; Trans. Adol.
No. 15,618; Net 657; 700 F.; June 2, 1930; 120 mm.; Trans. Adol.
No. 15,773; Net 684;1,000 F.; June 7, 1930; 130 mm.; Trans. Adol.
No. 15,823; Net 685; 700 F.; June 9, 1930; 125 mm.; Trans. Adol.
No. 16,101; Net 713; 700 F.; June 17, 1930; 400 mm.; Adult
No. 16,536; Net 762; 1,000 F.; July 2, 1930; 146 mm.; Trans. Adol.
No. 16,593; Net 765; 500 F.; July 3, 1930; 200 mm.; Trans. Adol.
No. 16,727; Net 776; 500 F.; July 5, 1930; 110, 140, 150 mm.; Trans. Adol.
No. 16,779; Net 784; 500 F.; July 7, 1930; 185 mm.; Trans. Adol.
No. 16,954; Net 796; 1,000 F.; July 9, 1930; 270 mm.; Trans. Adol.
No. 17,518; Net 823; 700 F.; Sept. 1, 1930; 440 mm.; Adult.
No. 17,760; Net 835; 500 F.; Sept. 3, 1930; 140 mm.; Trans. Adol.
No. 17,818; Net 842; 600 F.; Sept. 4, 1930; 148 mm.; Trans. Adol.
No. 19,246; Net 933; 600 F.; Sept. 23, 1930; 126 mm.; Trans. Adol.
No. 19,352; Net 944; 400 F.; Sept. 25, 1930; 135 mm.; Trans. Adol.
No. 19,566; Net 966; 400 F.; Sept. 30, 1930; 144 mm.; Trans. Adol.
No. 19,974; Net 967; 500 F.; Sept. 30, 1930; 202 mm.; Trans. Adol.
No. 20,515; Net 983; 500 F.; June 2, 1931; 61 mm.; Adolescent
No. 20,637; Net 994; 900 F.; June 4, 1931; 110 mm.; Trans. Adol.
No. 20,647; Net 996; 400 F.; June 5, 1931; 110 mm.; Trans. Adol.
No. 20,746; Net 1,005; 700 F.; June 6, 1931; 130 mm.; Trans. Adol.
No. 20,747; Net 1,006; 800 F.; June 6, 1931; 160 mm.; Trans. Adol.
No. 20,857; Net 1,014; 500 F.; June 13, 1931; 128 mm.; Trans. Adol.
No. 20,935; Net 1,030; 200 F.; June 22, 1931; 140 mm.; Trans. Adol.
No. 20,976; Net 1,037; 300 F.; June 25, 1931; 120 mm.; Trans. Adol.
No. 21,021; Net 1,042; 100 F.; June 26, 1931; 27 mm,; Larva
No. 21,018; Net 1,043; 300 F.; June 26, 1931; 115 mm.; Trans. Adol.
No. 21,115; Net 1,048; 300 F.; June 27, 1931; 214 mm.; Trans. Adol.

No. 21,116; Net 1,052; 300 F.; July 6, 1931; 120, 135, 135 mm.; Trans. Adol.
No. 21,153; Net 1,058; 300 F.; July 7, 1931; 110 mm.; Trans. Adol.
No. 21,222; Net 1,067; 300 F.; July 9, 1931; 120, 125 mm.; Trans. Adol.
No. 21,269; Net 1,072; 300 F.; July 10, 1931; 206 mm.; Trans. Adol.
No. 21,270; Net 1,073; 300 F.; July 10, 1931; 110, 120, 125, 130, 147 mm.;
                                                          Trans. Adol.
No. 21,325; Net 1,078; 300 F.; July 11, 1931; 120 mm.; Trans. Adol.
No. 22,114; Net 1,097; 700 F.; July 24, 1931; 17 mm.; Larva
No. 21,539; Net 1,101; 400 F.; July 25, 1931; 130, 136 mm.; Trans. Adol.
No. 21,549; Net 1,103; 600 F.; July 25, 1931; 147 mm.; Trans. Adol.
No. 21,625; Net 1,110; 600 F.; July 27, 1931; 216 mm.; Trans. Adol.
No. 21,634; Net 1,112; 900 F.; July 27, 1931; 136 mm.; Trans. Adol.
No. 21,693; Net 1,114; 400 F.; July 29, 1931; 150 mm.; Trans. Adol.
No. 21,983; Net 1,137; 600 F.; Aug. 6, 1931; 245 mm.; Trans. Adol.
No. 21,952; Net 1,139; 700 F.; Aug. 6, 1931; 125 mm.; Trans. Adol.
No. 22,498; Net 1,189; 700 F.; Aug. 17, 1931; 142 mm.; Trans. Adol.
No. 22,962; Net 1,241; 500 F.; Aug. 31, 1931; 127 mm.; Trans. Adol.
No. 23,038; Net 1,243; 700 F.; Aug. 31, 1931; 150 mm.; Trans. Adol.
No. 23,044; Net 1,248; 600 F.; Sept. 1, 1931; 195 mm.; Trans. Adol.
No. 23,079; Net 1,258; 900 F.; Sept. 3, 1931; 34 mm.; Larva
No. 23,140; Net 1,265; 1,000 F.; Sept. 4, 1931; 36 mm.; Larva
No. 23,209; Net 1,276; 500 F.; Sept. 9, 1931; 150 mm.; Trans. Adol.
No. 23,308; Net 1,291; 600 F.; Sept. 12, 1931; 125 mm.; Trans. Adol.
No. 23,397; Net 1,296; 600 F.; Sept. 14, 1931; 110 mm.; Trans. Adol.
No. 23,377; Net 1,300; 1,000 F.; Sept. 14, 1931; 155 mm.; Trans. Adol.
No. 23,455; Net 1,301; 50 F.; Sept. 15, 1931; 46 mm.; Larva
No. 23,549; Net 1,311; 300 F.; Sept. 16, 1931; 57 mm.; Larva
No. 23,577; Net 1,316; 800 F.; Sept. 17, 1931; 130 mm.; Trans. Adol.
No. 23,955; Net 1,339; 700 F.; Oct. 29, 1931; 177 mm.; Trans. Adol.

Serrivomer brevidentatus Roule and Bertin 1929

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

7 specimens: May to October, 1930 and 1931; 500 to 800 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 73 to 512 mm.

DESCRIPTION OF ADULT
(Figs. 34, 35 C, 36 C).

COLOR: Black, with a fragile coating of silver skin, which, when fresh, gives off a high bronzy iridescence.

PROPORTIONS (from the 512 mm. Bermuda specimen): Depth in length 30; head in length 5.8; eye (horizontal) in head 17; eye is horizontally elongate; maxillary reaching well beyond vertical from posterior margin of eye; snout in head 2.9; snout to dorsal in length 3; snout to anal in length 3.6.
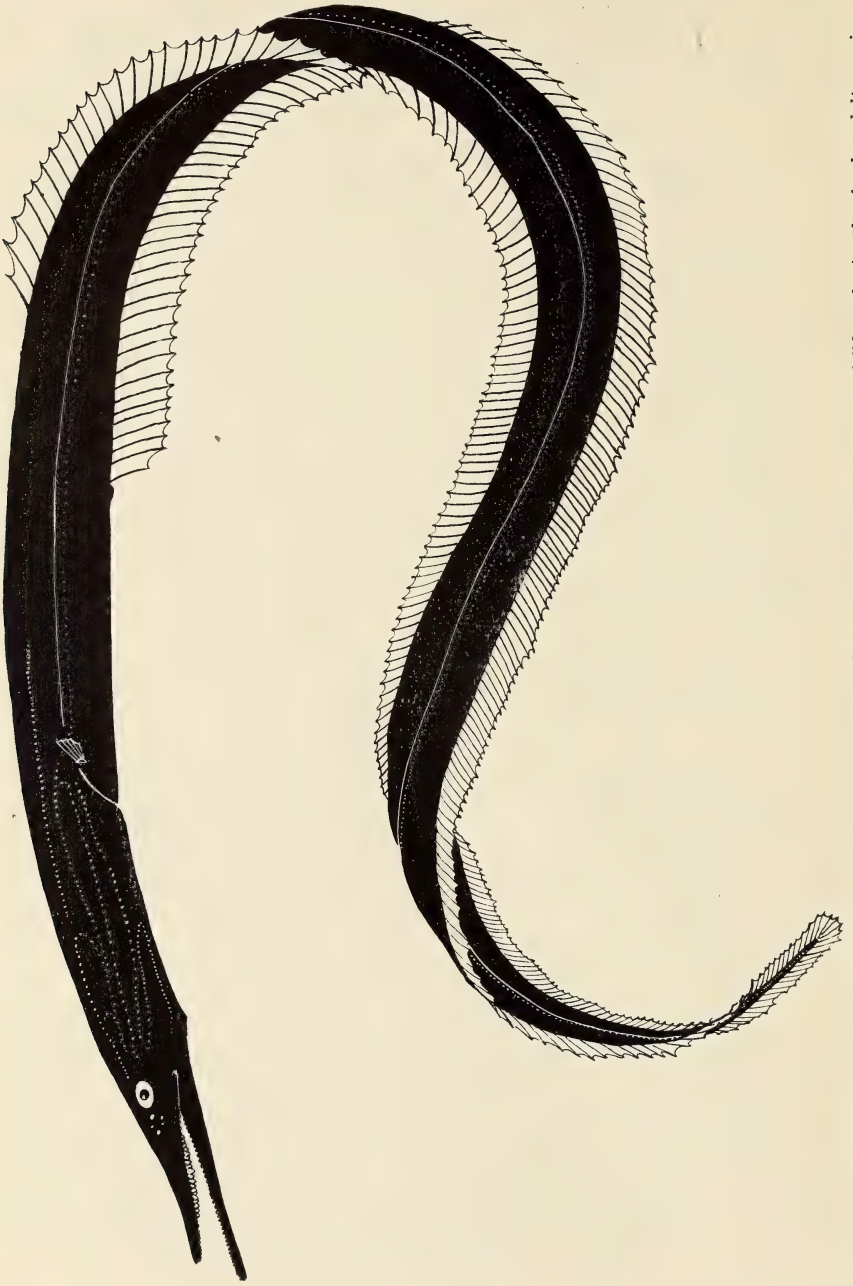
Fig. 34. *Serrivomer brevidentatus.* (x .7). *The pores indicated by the tiny white dots were visible only in the fresh, adult specimen.*
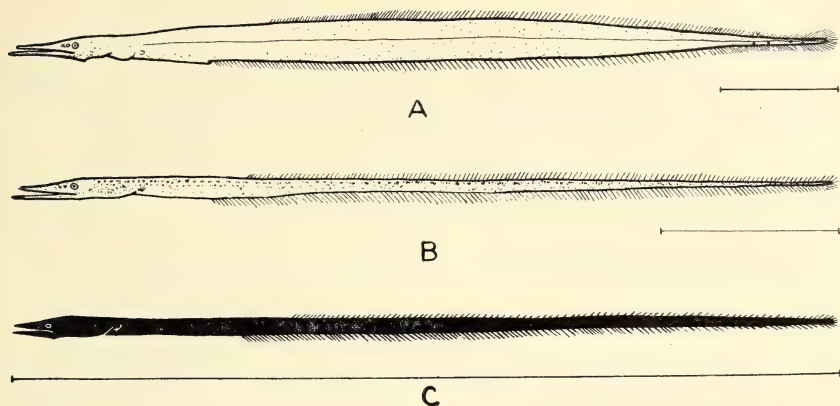
Fig. 35. *Serrivomer brevidentatus*. A, adolescent, 73 mm.; B, transitional adolescent, 110 mm.; C, adult, 512 mm.

TEETH: The dentition has been described in detail on p. 58.

FINS: Pectoral rays 6 or 7, very delicate, equal in length to horizontal diameter of eye, inserted at upper angle of branchial cleft. Dorsal rays 160 to 181, commencing well behind the anal origin, above 13th anal rays, at a distance 1.3 times the post-orbital length of the head. Anal rays 159 to 173, longer than those of dorsal. The rays of both fins are longest, and the spaces between successive rays greatest, in the anterior halves, behind the first 10 or 15 rays. Caudal rays 5 or 6, scarcely distinguishable from those of dorsal and anal, with which the caudal fin is confluent.

VERTEBRAE: Largest Bermuda specimen, 151; figures given by Roule & Bertin, 1929, 143-155; figure given by Trewavas, 1932, 171.

BRANCHIOSTEGALS: 7 to 8.

OSTEOLOGY: (Figs. 37-40). The skeleton of *S. brevidentatus* is exactly similar to that of *S. beanii* except for the following characteristics:

1. The ethmo-vomer is shorter and more slender.
2. The preopercle is less extensive.
3. The opercle is quadrilateral, with rounded corners, not triangular, and the closely applied subopercle consequently does not elbow sharply.
4. The proximal ends of the first five branchiostegal rays do
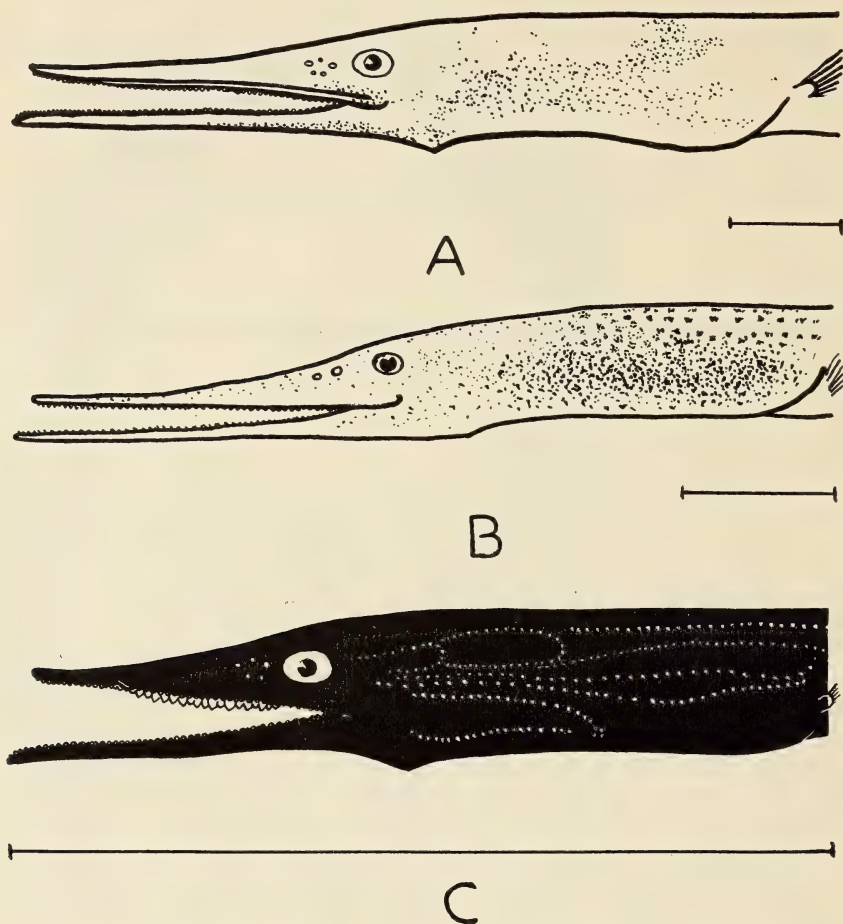
Fig. 36. *Serrivomer brevidentatus.* A, adolescent, standard length 73 mm.; B, transitional adolescent, 110 mm.; C, adult, 512 mm.

not project beyond the antero-dorsal margin of the hyoid arch.

5.   There is only one basibranchial, not two.

6.   The coracoids are more rudimentary, showing no connection with either cleithrum or finrays.

7.   The dorsal origin is at the level of the 32nd to 34th (the latter figure according to Trewavas, *loc. cit.*, p. 651) vertebra, not at about the 27th, and that of the anal at the 25th

to 26th (latter according to Trewavas), not at about the
21st.

8. The neural spines of the anterior part of the vertebral col-
umn are shorter, and die out close behind the origin of the
anal fin, at about the 29th, not the 38th vertebra.

9. Epineurals are present on 14 vertebrae, not 11.

10. The neural arch of the last (urostyle) vertebra is more pos-
teriorly extended, sheathing more of the notochord.

11. The third (ventral) hypural is larger, with two instead of
only one foramina.

Minor differences, such as the increased anterior expanse
of the hyomandibular, may be attributed to the larger size (512
mm.) of the stained specimen of *S. brevidentatus*; as the largest
S. beanii measures only 440 mm. To the same cause is probably
due the relatively larger ethmovomer and sphenotic of the Ber-
muda *S. brevidentatus* when compared with Trewavas's 160 mm.
stained specimen of the same species (*loc. cit.*, Pl. III).

DIGESTIVE and REPRODUCTIVE SYSTEMS: (Figs. 41, 42).
These seem identical with those of *S. beanii*. The 512 mm.
stained specimen was a female with the eggs poorly developed.

DEVELOPMENT

No differences are apparent between young specimens of
S. brevidentatus and corresponding examples of *S. beanii*, ex-
cept for the diagnostic character of the attachment of the
branchiostegal rays. (p. 58). At least three of the transitional
adolescents were females, as well as the single adult.

The seven specimens of *S. brevidentatus* are distributed as
follows among the growth stages:

Adolescent, 73 mm.: 1 specimen.
Transitional Adolescents, 110 to 280 mm.: 5 specimens.
Adult, 512 mm.: 1 specimen.

ECOLOGY

SEASONAL and VERTICAL DISTRIBUTION: The present mate-
rial is too scanty for any general conclusions. It may be
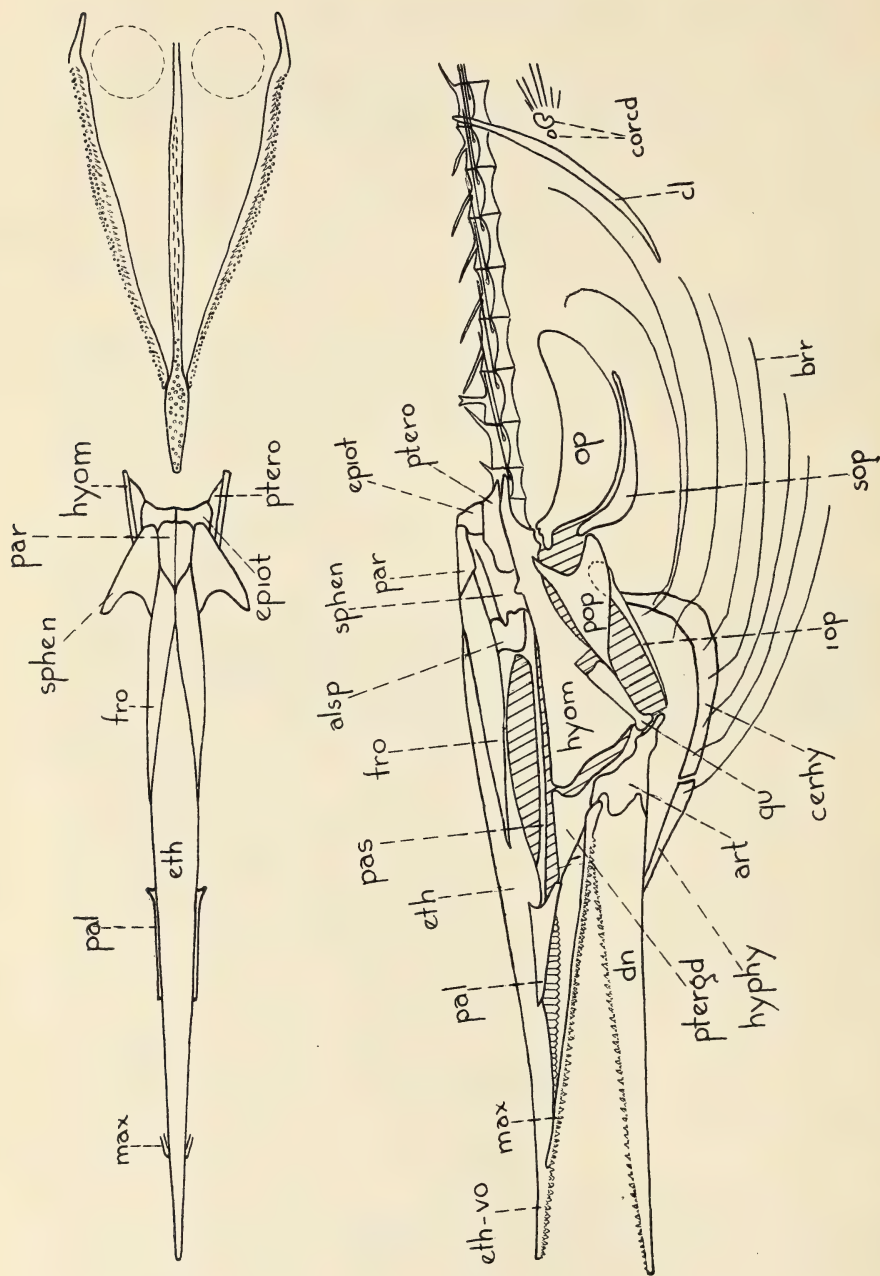
Fig. 37. (upper left). *Serrivomer brevidentatus.* Skull of adult, dorsal view; standard length 512 mm. (x 1.7).
Fig. 38. (upper right). Same, teeth of upper jaw and vomer, ventral view. (x 1.7).
Fig. 39. (lower). Same, bones of head, pectoral girdle and anterior part of vertebral column, lateral view. (x 1.7).
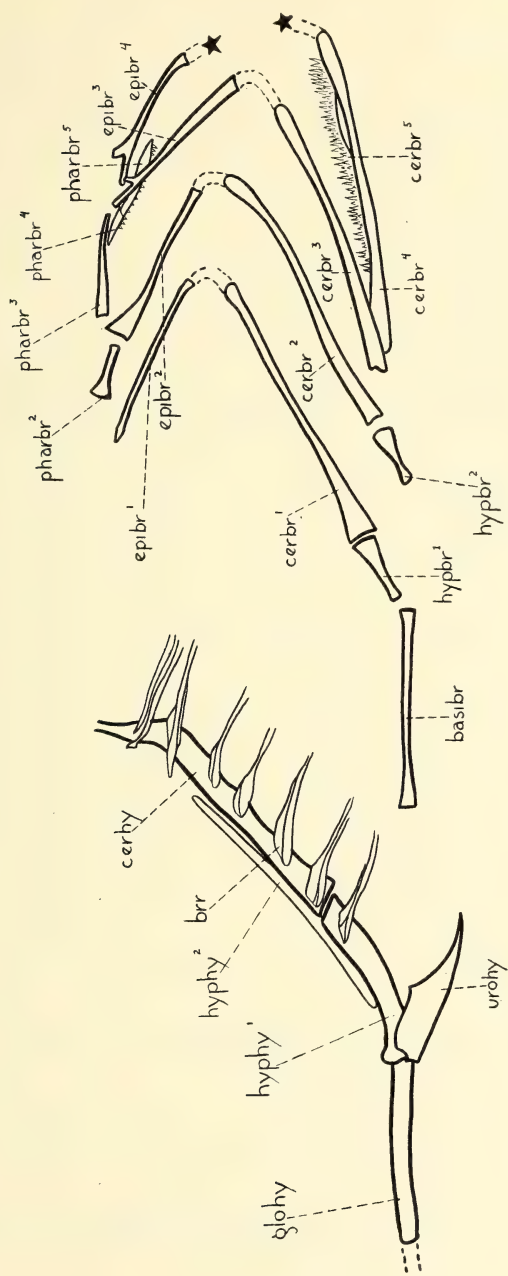
Fig. 40. *Serrivomer brevidentatus.* Hyoid and branchial apparatus of adult, standard length 512 mm.   (x 2.3).
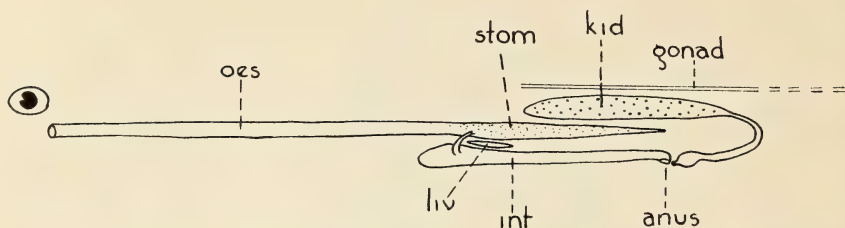
Fig. 41. *Serrivomer brevidentatus.* Viscera of adolescent, standard length 73 mm.; oes: oesophagus; stom: stomach; liv: liver; int. intestine; kid: kidney. (x 8.6).

remarked, however, that *Serrivomer brevidentatus* was taken throughout the trawling season from May to October, between 500 and 800 fathoms, the average depth being 657 fathoms. The single adolescent (73 mm.) was taken in late October.

ABUNDANCE: In contrast to *Serrivomer beanii,* which is by far the most abundant of Bermuda deep-sea eels, *Serrivomer brevidentatus* is one of the rarest of all Bermuda deep-sea fishes.

FOOD: Remains of crustaceans were found in several of the stomachs.

ENEMIES, VIABILITY, HABITAT OBSERVATIONS: See *S. beanii,* p. 90.

STUDY MATERIAL

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of each specimen of *Serrivomer brevidentatus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the
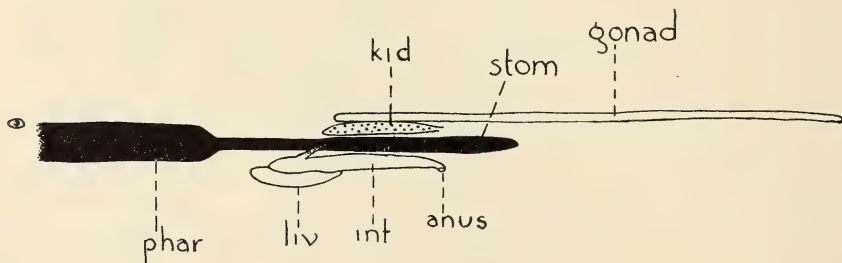
Fig. 42. *Serrivomer brevidentatus.* Viscera of adult, standard length 512 mm.; phar: pharynx; other abbreviations as in Fig. 41. The kidneys and gonads were slightly damaged so that it was impossible to trace the courses of their ducts. (x .5).

Bermuda coast described in ZOOLOGICA, Vol. XVI, No. 1, p. 5., and Vol. XX, No. 1, p. 1. "Trans. Adol." stands for "Transitional Adolescent."

No. 15,211; Net 612; 600 F.; May 21, 1930; 157 mm.; Trans. Adol.
No. 16,956; Net 778; 700 F.; July 5, 1930; 220 mm.; Trans. Adol.
No. 16,962; Net 793; 700 F.; July 9, 1930; 512 mm.; Adult
No. 18,071; Net 860; 600 F.; Sept. 8, 1930; 280 mm.; Trans. Adol.
No. 20,605; Net 992; 700 F.; June 4, 1931; 265 mm.; Trans. Adol.
No. 23,930; Net 1,336; 500 F.; Oct. 29, 1931; 110 mm.; Trans. Adol.
No. 23,962; Net 1,340; 800 F.; Oct. 29, 1931; 73 mm.; Adolescent.

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VOLUME XXI

Part I

Numbers 1 and 2

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ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS
OF THE
NEW YORK ZOOLOGICAL SOCIETY

1.

The Reproductive Habits of the North American Sunfishes (Family Centrarchidae). By C. M. Breder, Jr., New York Aquarium.

(Plates I-VII; Text-figures 1-6)

INTRODUCTION.

The fresh water sunfishes, Centrarchidae, a large but rather uniform family confined to North America, are well known even to those not concerned with biological matters. Their nests, excavated in shallow places, usually on sandy shores, are familiar objects in late spring and early summer. These have often been described and discussed in more or less detail in both lay and technical publications. Notwithstanding, there are numerous features of their reproduction that remain to be studied in order to understand better the particular mode of life that these fishes have adopted. The present contribution, therefore, has been prepared to extend our knowledge of these fishes in greater length, with special reference to the philosophical implications of certain features of reproductive behavior. The habits of these fishes are so closely similar in many items that the paper has been arranged by elements in the common reproductive pattern. A systematic list of species follows this, with explanations of particular differences.

The studies referring to *Eupomotis* at Pines Lake, New Jersey, were made possible through the courtesies of Mr. H. I. Hartshorn of that place. His assistance in the field was of considerable value, especially in regard to the preparation of the chart of nest distribution. All observations made on Kensico Lake, Wampus Pond and Byram Lake were possible only through the kind permission of Mr. Herman Forster, Deputy Commissioner of Water Supply of New York City, as these waters are all part of the drainage basins supplying that place.

The photographs of *Ambloplites* and *Eupomotis* in captivity were taken at the New York Aquarium by Mr. S. C. Dunton of that institution.

THE REPRODUCTIVE SEASON.

All the sunfishes spawn in the late spring or early summer. Generally the largest species, the so-called black basses, *Aplites* and *Micropterus*, are the earliest and although some of the smallest may start early, their season is apt to last the longest, *e.g. Enneacanthus, Mesogonistius*, in any one region.

If for one reason or another the spawning season is passed without reproduction, a reabsorption of the eggs results without apparent injury to the fish. This naturally happens frequently in aquaria where crowding may make spawning impossible. Specimens of *Ambloplites rupestris* (Rafinesque) that have lived at the New York Aquarium for a period of eighteen years at this writing and constitute one of the records of longevity of that institution, Mellen (1919) and Flower (1925 and 1935), may be used as an illustration. That this frequent passing of the season without spawning has not destroyed the genital tract is illustrated by the fact that reproduction will ensue if a suitable environment, usually a reduction of crowding, is provided. See Breder (1928), as well as the remarks on that species, and illustrations, in this paper.

Lest it be thought that a long life in an aquarium is an essential part of the failure to reproduce each season, it may be pointed out that such occurrences may take place in a state of nature. For example, Mr. Herman Forster caught a 19-inch *Micropterus dolomieu* in Kensico Lake on July 4, 1935. The ovaries of this fish were turgid with large eggs, although all the black bass nests in this lake were but a memory at that date. Young bass had been out of the influence of their parents for some time and the schools had just broken up. Scattered remnants of schools composed of a few specimens could be found, in all of which the fish were over 10 mm. in length, and they—in all probability—were of the most backward ones. The ovaries of the fish under discussion were hemorrhagic, the spleen was grossly enlarged, the liver was mottled and the gall-bladder somewhat enlarged. The fish externally appeared to be in vigorous health and harbored no parasitic cysts in the ovaries, not uncommon in these fish, Moore (1925 and 1926) and Bangham (1927), or any other evident parasites. The inference may be taken that at least some of the visceral peculiarities noted were associated with the early stages of reabsorption of the post-season eggs.

Apparent differences in the reproductive dates are probably to be associated in most cases with the speed of the rise to the temperature at which they spawn. This may be conditioned by the size and depth of the pond or lake, the temperature and amounts of water in the inflowing streams, rainfall and general weather conditions, since all influence the responsiveness of natural waters to seasonal change. It may also be mentioned that the reaching of a certain absolute thermal value has relatively little to do with the actual spawning. It is rather the antecedent temperatures, their duration and fluctuations, that determine to a considerable measure the metabolic rate of the gonadal development in such poikilothermal animals.

True to their common name, as soon as the water warms sufficiently to cause them to disperse from their winter hibernation, the sunfishes move into shoal waters and bask in the early spring sunshine. The temperature at which the hibernating habit breaks up is 10° C. for *Lepomis auritis*, as shown by Breder and Nigrelli (1934). This species, which forms a wintering school or hibernium, resembles *Aplites salmoides* to this extent, Townsend (1916), and *Acantharcus pomotis*, and to a lesser extent *Pomoxis sparoides*. Other species, such as *Helioperca macrochira*, *Apomotis cyanellus*, *Eupomotis gibbosus*, *Chaenobryttus gulosus*, *Ambloplites rupestris* and *Enneacanthus gloriosus*, while quiet below this temperature, did not show such aggregating habits in the aquarium, at least. Passing from this prespawning condition the more aggressive males make their way to the shore line. The females either follow or remain in deeper water until some later time.

There is nothing that can be considered a migration, under ordinary circumstances, other than the movement inshore from deeper waters. Meek (1916), however, ascribes an anadromous migration to the Centrarchidae for which there seems to be no evidence whatever.

The Construction of the Nest.

The males alone are concerned with the construction of the nest. At this time of year, before actual construction is commenced, there is a centrifugal influence between fish and fish which becomes more intense in shallow water. In *Eupomotis gibbosus, Lepomis auritus* and *Aplites salmoides,* for example, during the early spring several fishes may be found resting quietly side by side in relatively deep water almost in the form of a school. These make little sallies into shoal water. As soon as they reach the area destined for nesting a dispersing influence sets in which scatters them. There may be a little fighting but usually there is little more than a few desultory chases. Presumably, the entering of the warmer shore stratum of water increases activity practically instantly. Another factor would appear to be that of direct solar radiation. At least, sunfish are much more active and aggressive on bright, sunny days. In fact, the sudden passage of a cloud usually causes their retreat to deeper water. As soon as it passes they immediately return to their interrupted task. This effect carries all through the reproductive procedure, even interrupting the mating act.

Extensive observations on the effect of sunshine were made on *Eupomotis gibbosus* in several places, which agreed perfectly with fewer made on *Lepomis auritus, Aplites salmoides* and *Micropterus dolomieu.* Regarding the behavior of nesting *Eupomotis* in relation to sunlight, some rather striking observations were made at Pines Lake. A well-formed colony was being studied on a day on which fleecy clouds passed rapidly and more or less regularly across the face of the sun. This colony is illustrated by Pl. I, Fig. 1. While the sun was bright and unclouded the fish remained on their nests pursuing their usual activities of fanning eggs, clearing nests to receive eggs and courting visiting females, as well as spawning. On the passage of a cloud before the sun they all retreated from their nests and remained headed toward them in a more or less open school that was quite quiescent, with the exception of three that were inactively resting over their nests at the time of the change. These remained where they were. As the sun again made its appearance the others would rapidly return to their nests and resume their activity. Readings on a Weston exposure meter used for photographic work showed that the light reflected from the surface of the water in sunshine reached or exceeded 1,000 on the scale of that instrument. The above-described phenomenon occurred when the values fell below 700. On dull days at Llewellyn Lake there was seen to be no activity, the fishes remaining quietly on their nests. The same was true at night in both places. A sunfish on its nest at night, photographed by flashlight, is shown by Pl. II, Fig. 2. The flashlight used to find them at night usually drove them off their nests. If, however, the light was held steadily on a nest for a few minutes the fish would return, and in one case such a male tried to mate with a wandering female that had probably been attracted by the light. It would consequently seem to follow that reproduction takes place only in bright light and that other times are spent quietly resting over the eggs with only a nominal fanning of them. In this connection it might be mentioned that the water of Pines Lake was of a somewhat greater transparency than that at Llewellyn Lake, which may also have some bearing on the depth at which various sized nests were elaborated. Whether visible radiation or radiant heat is responsible for the effect noted could not be determined, but might well be made the subject of future experiment. There can be no doubt, however, that the fishes were able to see each other in the dull periods at Pines Lake. It is equally certain that there was no change in the water temperature during these short periods.

The selection of the nesting site appears to be largely controlled by two opposed influences: the centrifugal effect of breeding males, on the one hand, and the limitation of suitable bottom, on the other, Breder (1935b). Fish culturists have long known that numerous boxes open on one side per-
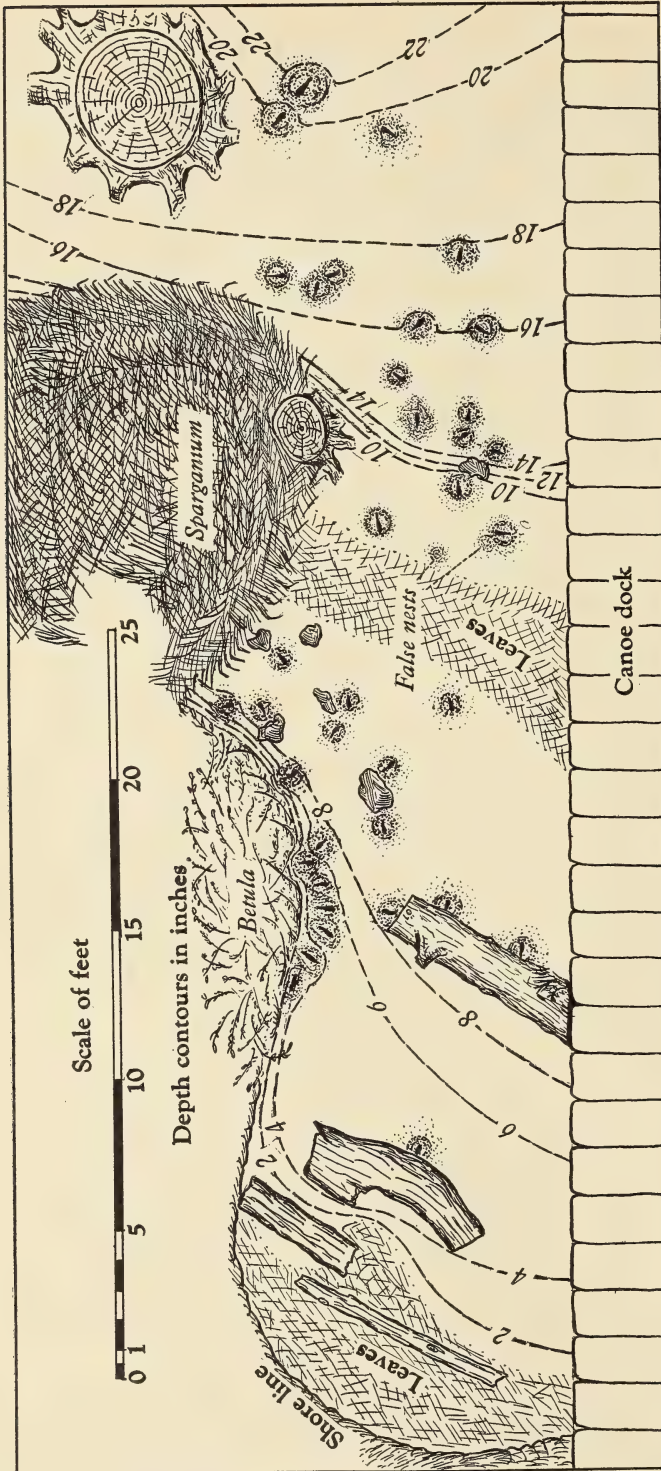
Text-figure 1.

Chart of a colony of *Eupomotis gibbosus* nests at Pines Lake, New Jersey. This is a different colony from that illustrated in Pl. I, Fig. 1. The two areas marked "False nests" represent sites on which nests were apparently started and then abandoned. A few such spots are usually to be found in moderately large colonies.

mit more nests of the black basses per given area. These really serve as "blinders" from one nest to another. A third factor appears to be depth of water. That is to say, the smaller the fish and the smaller the nest, the more shallow the water standing over it will be. A number of nests were measured in this regard at Pines Lake, a location where this was the only species of sunfish to be found. These are used only because where mixed species spawn they frequently appropriate each other's nests, as will be subsequently discussed. Although such probably occurs between individuals of the same species, our figures do not suggest it. Table I gives this data and the actual nests are illustrated by Text-fig. 1, together with pertinent data. It will be noted that there is a considerable disposition to nest close to objects, especially on the part of those nesting in shallow water. None in water of less than seven inches nested free of some object protecting the nest from one side. Patches of leafy bottom were left strictly alone and those seeking the most shallow water permitted considerable crowding. While these data are hardly enough to treat statistically, the second part of Table I indicates clearly that under five inches 100% nested close to some object. This percentage falls rapidly and evenly to zero for nests more than fifteen inches deep. A consideration of Text-fig. 1 shows that this was not because of an absence of objects to nest against in the deeper water. Note especially the large stump, often a favorite site for fishes in shallow water. More than one-third of these nests were found in water between five and ten inches in depth. This we believe to be referable to the size of the fish—an item to be discussed at another point. The increase in size with water depth is also clearly indicated in Table I. The greater tolerance of nearby nests in water of less than five inches, 85%, would seem to be referable to a lesser amount of available space close to the shore line. The depth contours in Text-fig. 1 give a measure of the amount of available space in the various depth ranges, as expressed in Table I. The number of nests in each depth range, however, is not proportional to the available area. If figures were available it might be shown, however, that the numbers of various sized fish compared with the suitable area for their size might determine the extent of crowding.

Similar measurements were made in Llewellyn Lake. At this place the fishes were found to be of a considerably larger size and some of the small non-breeding fishes were found to be as big as the largest fish of Pines Lake. The reasons, probably ecological, are not evident at this writing. Numerous recently abandoned nests of *Aplites salmoides,* which spawns earlier, were in evidence as well as some actively nesting *Lepomis auritus.* In measuring and studying the nests of *Eupomotis* in this lake it soon became apparent there was a frequent disparity in size between some nests and their occupants, which was not found in Pines Lake. In both cases only such nests were considered for study as were occupied by a defending male. This feature, it was finally seen, was caused by the appropriation of an already constructed nest by another species, Breder (1935c). Thus *Lepomis* was seen to occupy old *Aplites* nests of sizes that could never have been built by the occupant. Likewise *Eupomotis* occupied *Lepomis* nests and in two cases even those of *Aplites.* The proof of this condition was fully established when a *Lepomis* on a nest of an appropriate size was seen on the following day to have been supplanted by a *Eupomotis,* of much smaller size. Also, a similar case was seen in a single day between these two species, but over a nest that had originally been constructed by *Aplites.* The typical defense reactions occurred on disturbance, but no eggs were removed from either. Table II gives measurements of nests in this lake. The tabular arrangement does not clearly express these differences, but set forth in graphic form, as in Text-fig. 2, the relationship of nest size to species and nest size to depth becomes evident. The smaller fish of Pines Lake form a rather uniform group increasing in size with depth. Here there was no influence from other species and the brooding fish were seen to "fit" their nests; that is, they

were approximately one-half the diameter of the nest they occupied. In Llewellyn Lake nests of large size, nearly twice as large, were built in water of the equivalent depth selected by the Pines Lake fishes. The fishes on

TABLE I.

Nesting data on *Eupomotis* at Pines Lake, N. J.

All measurements in inches.

Water Depth	Diameter of Nest Floor	Diameter of Nest Rim	Adjacent to[1] Another Nest	Adjacent to[1] a Solid Object
4½	5	9	..	*
4½	Irregular	Irregular	*	*
4½	"	"	*	*
4½	"	"	*	*
4½	"	"	*	*
4½	"	"	*	*
4½	"	"	*	*
7	"	"	*	..
7	"	"	..	*
7	"	"	*	*
8	6	11	..	*
8½	Irregular	Irregular	*	*
8½	5	9	..	*
9	6	11	..	*
9½	5	9	..	*
9½	..	..	*	*
9½	..	..	..	*
9½	5	9	..	*
9½	5	9	..	*
9½	5	9	..	..
13½	5½	9	..	..
13½	6	9	..	..
14½	5½	9	..	*
14½	5	8	*	..
14½	5	8	..	*
15	5	8	..	..
15	5	8	..	..
15	..	..	*	..
16	5½	8½	..	..
16	5½	8½	..	..
17	6	9	*	..
17	6	9	*	..
17	6	9	..	..
18	5½	8½	..	..
19	5	10	..	..
20	8	12	*	..
22	8	15	*	..
Average	5.6	9.4		

Data according to depth ranges.

Depth Range	No. of Nests	% of Nests	Average Floor dia.	Average Rim dia.	% Adjacent to Another Nest	% Adjacent to a Solid Object
0-5	7	19	5	9	85	100
5-10	13	36	5+	9+	31	92
10-15	8	21	5+	8—	25	25
15-20	8	21	6—	9+	37	0
over 20	1	3	8	15	100	0

[1] An asterisk (*) indicates presence.

these nests fitted them as to size. The other *Eupomotis* in Llewellyn Lake did not equal the radius of the nests they occupied, and it is believed these nests were constructed by other species; the circled ones by *Lepomis* and those in triangles by *Aplites*. The latter is certainly the case and probably most of the former. Some of these, however, may be cases of smaller *Eupomotis* moving to deeper water and larger nests of the same species. It is to be especially noted that those nests used for the construction of Text-fig. 2 are by no means all that were considered. They are only those on which it was possible to obtain sufficiently accurate measurements. Irregularly shaped nests, those with vague outlines, due to the nature of the bottom, etc., were rigorously excluded.

It is possible that angling may be a contributing factor to the sunfishes' appropriation of other nests in Llewellyn Lake, for it is a rather small body

TABLE II.

Nesting data on *Eupomotis* and *Lepomis* at Llewellyn Lake, N. J.

All measurements in inches.

Water Depth	Diameter of Nest Floor	Diameter of Nest Rim	Occupant	Probable Builder
3	....	10	*Eupomotis gibbosus*	Occupant
4½	11	13	"	"
5	12	15	"	"
5	....	14	"	"
5½	10	12	"	"
5½	14	18	"	"
5½	....	9	"	"
6	11	13	"	"
6	19	21	"	*Lepomis*
6	10	16	"	Occupant
6½	10	12	"	"
6½	....	12	"	"
7	....	16	"	"
7	11	16	"	"
7½	10	13	"	"
8	....	17	"	*Lepomis*
8	14	17	"	"
8	....	15	"	"
8½	15	18	"	"
9	18	20	"	"
9½	....	11	"	Occupant
9½	....	12	"	"
10	....	13	"	"
10	....	12	"	*Lepomis*
11	24	28	" [1]	"
11	16	19	"	"
11½	....	11	"	Occupant
12	15	18	"	*Lepomis*
15	....	25	"	"
17½	24	27	"	"
19	11	13	"	Occupant
28	27	30	"	*Aplites*
29	24	27	"	"
13	22	24	*Lepomis auritus*	Occupant
14	24	27	"	"
22	36	40	" [2]	*Aplites*

[1] Occupied by a four-inch *Eupomotis*.
[2] First seen occupied by a six-inch *Eupomotis* and later by a seven-inch *Lepomis*.

of water and angling by boys is carried on with considerable vigor. Since brooding sunfish will frequently take the hook while on their nests, it is not surprising that some would be left fatherless. In Pines Lake, on the other hand, which is a much larger body of water, there is little activity of this sort and the sunfish are mostly too small to take any but the smallest hooks. Such angling as is indulged in at this place is mostly trolling with artificial bait for pickerel and large bass that avoid the shallows used by the sunfish. That there are other factors involved as well, however, has already been indicated by the finding of two nests occupied by both *Eupomotis* and *Lepomis* over a period in which there was no angling. Similar observations concerning these three species were made in Kensico Lake in 1935. Since there were no variations the above comments cover the situation at this place equally well.
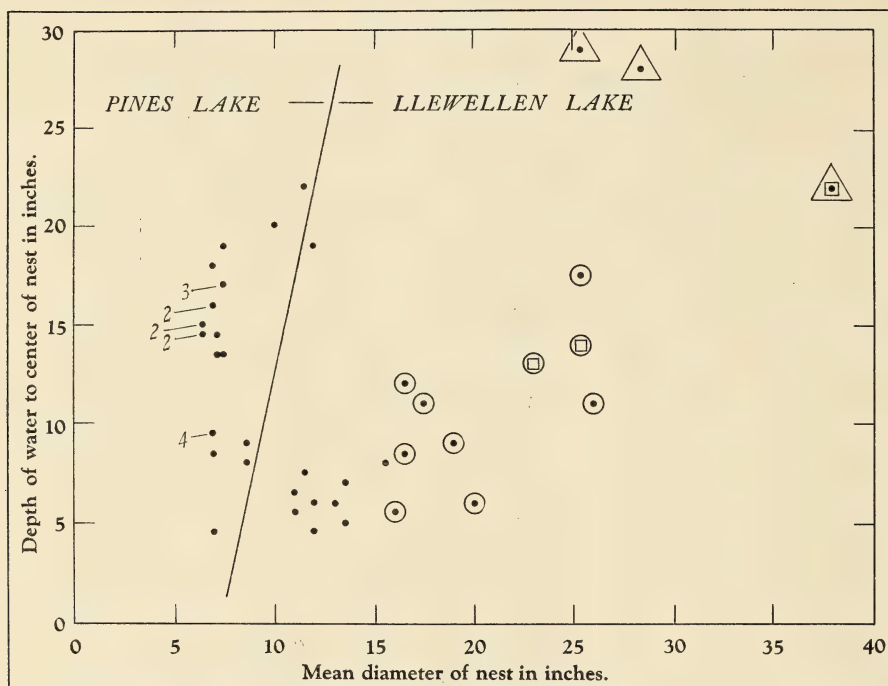
Text-figure 2.

Distribution of centrarchid nests at Pines and Llewellyn Lakes with regard to size and depth of water. The appropriation of nests by various species in the latter lake is indicated by symbols. Nests occupied by *Eupomotis gibbosus*, black spot; nests occupied by *Lepomis auritus*, light square; nests apparently constructed by *Lepomis*, light circle; nests apparently constructed by *Aplites*, light triangle; otherwise apparently constructed by the occupant, *Eupomotis*. The largest nest, built by *Aplites*, was occupied by both of the other species at different times. The figures in the Pines Lake section indicate more than one nest with identical measurements and water depth.

Small fish in these larger nests go through their customary activity, but instead of the building of a smaller nest within the larger being the result, the latter is simply swept clean, maintaining for most part its original contour. This is because the nest has already been excavated to a relatively hard bottom that the smaller fish could scarcely be expected to dislodge. On the

other hand the light sediment that tends to settle in the nest is readily swept over its rim on the slightest activity of the occupant. Apparently the only other mention of this kind of behavior is that of Hubbs (1919), who notes that he saw a *Eupomotis* take over the nest of *Helioperca macrochira*.

More or less casual observation of the nests of these two species over a period of many years has always revealed them to be located free from any overhanging object and where sunlight may reach them for at least part of the day, as of course is well known. Frequently they are adjacent to some submerged object, as shown in Text-fig. 1. It is in part this tendency that induces the basses to use the nesting boxes of fish culturists. Although a similar condition was noted on the other side of the canoe dock of Text-fig 1, absolutely none was constructed under its shelter. In another
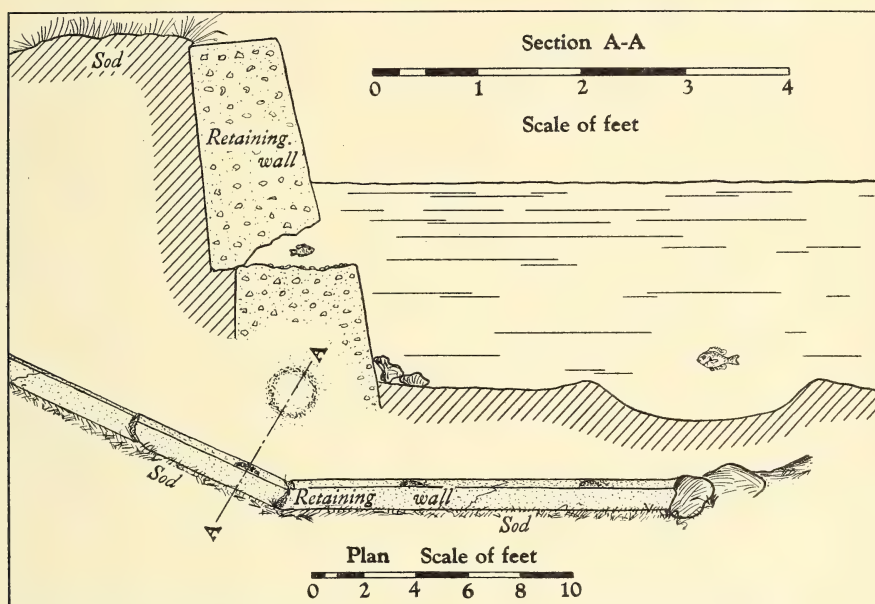
Text-figure 3.

Eupomotis gibbosus nesting in a crack in a concrete retaining wall and in an old *Aplites* nest. The plan view shows the edges of three nests under the pushed-back face of the broken upper part of the wall. Llewellyn Lake, New Jersey.

locality in Pines Lake where a small foot bridge connects an island with the mainland a similar condition obtained, but here a single nest was partly within the shelter of the bridge. At Llewellyn Lake, however, three nests were found to be constructed in a cavity formed by a large crack in a retaining wall. The occupants, just evident from above by their protruding snouts, would retreat into the crevice on disturbance instead of swimming some distance off. The condition here is illustrated in Text-fig. 3 in plan view and section. This nesting site suggested nothing so much as a suitable place for *Ameiurus* to spawn. Adjacent to this location was a *Eupomotis* occupying what was most certainly an old *Aplites* nest. This is also shown in Text-fig. 3.

It would seem likely that some part in the selection of nesting sites is controlled by the social organization of the population of the area involved.

The study of such would involve the constant study of ponds with known populations of a kind not at present available to the author. While the social hierarchy of fowls has been long known, the recent note on that of the lizard *Anolis* by Evans (1936) contains items that suggest that the territorial holdings of nesting fishes may involve similar elements.

Due to environmental difficulties it is sometimes impossible for fishes to find suitable places for their particular reproductive needs. Since the centrarchids require a certain number of factors having well marked limits, it is not unusual for them to find themselves in positions difficult for reproduction if indeed not impossible. These conditions are usually associated with fishes in a new environment, in which either the latter has been modified or the fish introduced artificially or intruded naturally. Probably in none of the illustrations which follow could the fish maintain a continuing population. For example: *Lepomis* normally inhabits quiet waters and is generally not found in rapidly moving water, at least during the spawning season. A curious condition has somewhat modified this matter of habitat preference, however, in the vicinity of New York City. Here the destruction of many trout streams by the building of artificial lakes for real estate development has occurred. The streams leaving these lakes have a summer temperature too high for trouts and have been subsequently invaded by pond fishes, although in many places they retain the physical characteristics that are generally associated with trout streams. This condition has been discussed in some detail by Breder and Redmond (1929). These warm streams, with nevertheless a swift current, both *Eupomotis* and *Lepomis* have successfully invaded. Their nest construction, however, is distinctly different from those of individuals residing in quiet ponds. The nests are widely scattered and each one is to be found on the downstream side of a large boulder or other form of shelter. The shore line, as such, plays no part in their location, the sole position-determining influence being shelter from the current, since these streams are usually not too deep for sunfish nesting at any distance from shore. The physical appearance of such a nest of *Lepomis auritus* is shown in both elevation and plan view by Text-fig. 4. This was prepared from a field sketch made from the banks of Waccabuck Creek in Pond Ridge Reservation, Westchester County, New York, on June 11, 1933. The arrows indicate the general direction of current. The numerous eddies and back flows at each irregularity of contour are not indicated. Of interest in this connection is the position of the fish immediately below the large rock protecting the nest. This will be discussed in another place, as it possesses special significance. The value to reproduction in the selection of such places in a current is evident, and in fact nesting in unprotected sites would be physically impossible. Examined uncritically this might well appear to be an expression of intelligence on the part of the nest-building fish. Actually it can readily be explained on purely mechanical grounds. Breder and Nigrelli (1934) have shown that this species can maintain a stationary position in a slight flow with less physical exertion than in absolutely still water, due to the effects of the exhalant water from their gill clefts, and that their stationary position always points them into a current, somewhat after the fashion of a weather vane. When living in such a flowing stream *Lepomis* habitually seek sheltered spots, for in other locations they can only maintain their position by continual active swimming movements. Consequently, stationary specimens showing little swimming or water-backing efforts act as positive indicators of the direction of flow. Fishes below a rock, as in Text-fig. 4, always hold the position indicated, for at about that point the current deflected to either side rejoins. Fishes closer to an object than the one shown are found at about right angles to it and face outward from a midline to meet the flow around the rock. Special irregularities in certain cases have always been found to be explainable, as indeed they must be for purely mechanical reasons. From this it follows

that the nest construction is elaborated in a place in which the fish can find a certain amount of rest—a point of minimum effort. The nest cannot be excavated when lying parallel to the rock, on account of its nearness, leaving the only possible position, shown in Text-fig. 4, the only one to be observed in the field. Fowler (1923) also found this species nesting in streams but makes no mention of the peculiarities here noted.

Such nests deviate from the circles found in really still water partly because of the tendency of the current to carry the dislodged particles downstream, resulting in a cavity with its longer axis parallel with the flow, as is shown. Even were it not for this effect of the flow the longer axis would still have the position, for the fish pointing so much in a single direction would excavate an oval space. Only in truly still water is a perfect circle possible, because there alone is there no mechanical differential inducing the fish to face mostly in one direction. In quiet ponds, where there is nevertheless a slow "creep" of current along the shore, the fish are found to mostly face into it. Under such conditions, the only slightly longer axis of the nearly circular nest is parallel to the current. In other ponds where there is a fairly steady on-shore wind, the fishes face the shore; that is, with the wind, and the long axis of the nest is parallel to it. This phenomenon, at first difficult to understand, exists simply because the surface water moving with the wind curls under at the shore line and travels outward along the bottom as a counter-current, to which the fishes react. This effect is not common but is mentioned to indicate how slight an influence may bear on this feature of the sunfish nest. The final check on the direction of water flow was made in all cases mentioned above by referring to the observed drift of small suspended particles.

In still water the normal direction of facing points to the source of disturbance; *e.g.*, another fish, the observer on shore, etc. This effect can only be seen distinctly in very still water and must be considered secondary to the mechanical force of the necessarily primary effect of water flow. The depth of the nest seems to be determined solely by the nature of the bottom, the fish fanning and excavating according to a standard pattern of behavior.

In ponds with very soft bottoms and no sandy or gravelly bars or shores, centrarchids are usually absent. A very sufficient reason for this will be seen in the following case. A small body of water, Wampus Pond, was drained about half way down for water supply purposes in the late winter. It lay in this condition through the 1935 spawning season. Before this operation the pond had a common type of shore line; mixed between rocky, sandy, gravelly and muddy and was well populated by three centrarchids, *Micropterus dolomieu, Eupomotis gibbosus* and *Lepomis auritus*. Being a very old natural pond its deeper portions were bottomed uniformly with soft flocculent mud and the detritus of countless generations of various aquatic plants. When the water was let down the new shore line left no sandy or gravelly places suitable for the spawning of sunfishes. There were some sheer vertical walls of smooth rock but the remainder of the shore line was covered with a soft, pasty mud of unknown depth, an oar not reaching bottom. Nevertheless, in season, the three species present attempted to construct nests.

In their efforts to clear away the detritus and reach some solid surface they succeeded simply in digging in deeper and deeper, so that eventually they were at the bottom of deep chimney-like pits. In the case of the two smaller species some of the holes were between a foot and two feet deep. While they were actively excavating, all that could be seen was a cloud of fine smoke-like silt pouring out over the lip of the excavation, that nevertheless managed to form a raised ridge around the hole, composed of the heavier material. At other times, when resting, the back of the fish could just barely be seen through a small cloud at the bottom of the pit, caused
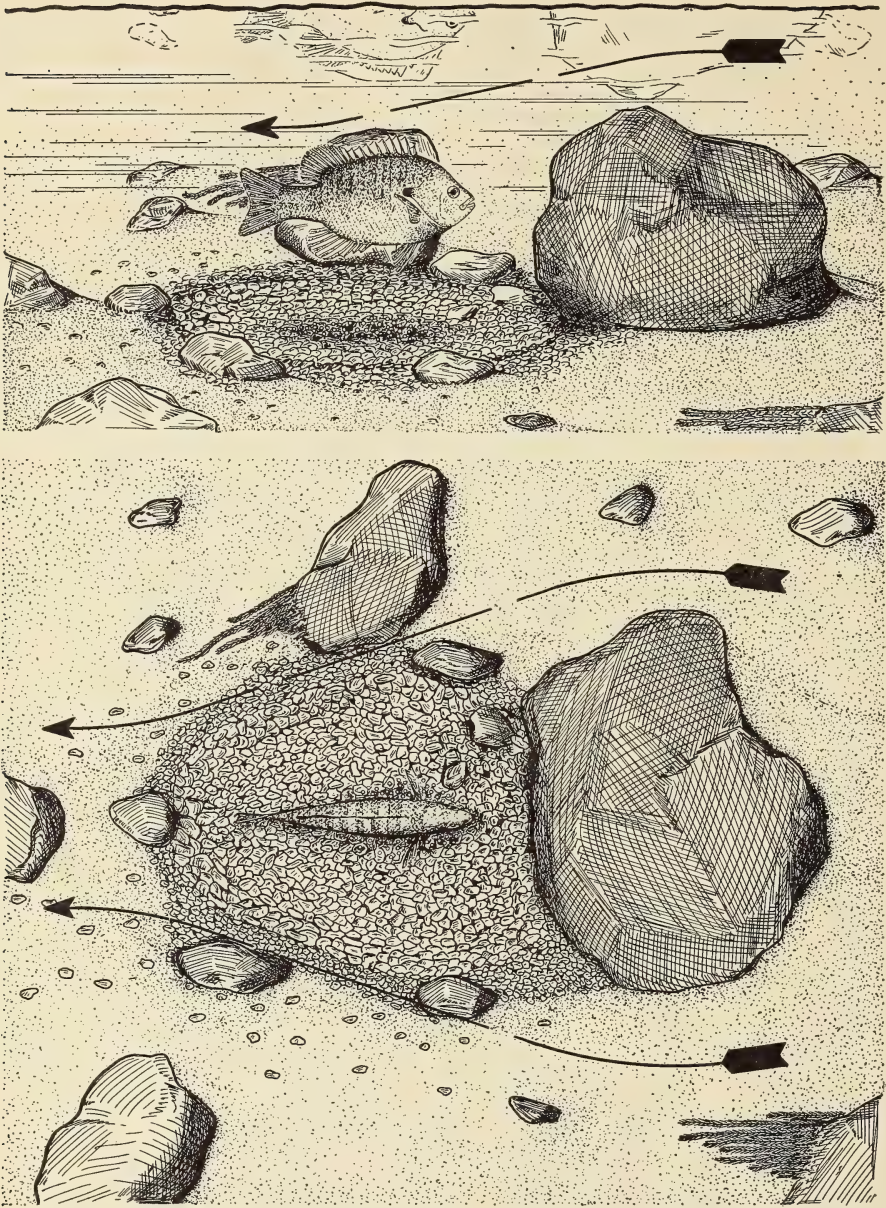
Text-figure 4.

Semi-diagrammatic sketch of *Lepomis auritus* nesting in a flowing
stream. (*Upper*). Elevation. (*Lower*). Plan view. The arrows indi-
cate the direction of the main flow only. Pound Ridge Reservation,
New York.

by respiratory and other movements. The general appearance of these
efforts is shown diagrammatically in Text-fig. 5.

Apparently there was no spawning in these nests, which basically may

have been caused by the male digging himself out of sight. Certainly in no case could a successful hatch be expected. The extreme opposite of this would appear to be a bottom so hard that nothing could be moved. What pass for nests are constructed under such conditions and are quite successful. The only requirement in this connection seems to be that the surface be substantially horizontal. Although sunfish eggs are slightly adhesive, apparently no species will use an inclined or vertical surface. At least there is no record of their ever having done so. The conditions at Wampus Pond could have led very easily to this if there were any such disposition on the part of the fish.

Helioperca macrochira was seen nesting on the floor of an ornamental pond at Lake Mohawk, New Jersey, apparently with entire success. The only thing here that the fish could brush away was a small amount of filamen-
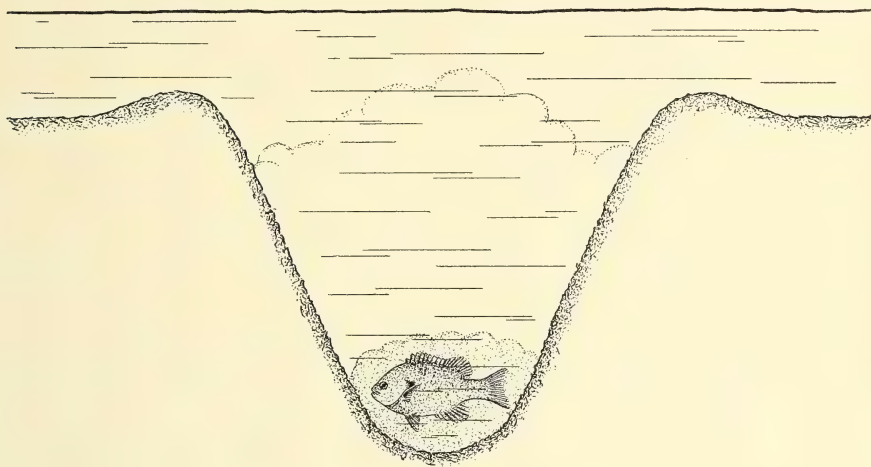
Text-figure 5.

Diagrammatic sketch of *Lepomis auritus* attempting to nest in a soft flocculent mud of unknown depth. The heavy cloud about the fish indicates the extent of turbidity caused by the resting fish. The upper outline of a cloud indicates the extent of the turbidity caused by nest building activity. At this depth the fish was unable to raise a cloud sufficient to leave the pit, thus reaching the limit depth for this kind of excavation. Wampus Pond, New York.

tous algae which then formed somewhat of a wall about the clean flat stone flooring. Perhaps a better illustration is provided by *Ambloplites* spawning in a tank at the New York Aquarium. This tank was floored with cement in which were embedded small protruding pebbles. Excavating efforts removed practically nothing but the slightest accumulation of fine material. Pl. III, Figs. 3 and 4, shows this type of bottom.

The lack of importance to the centrarchids of a bottom suitable for excavation is indicated by Wiebe (1935) who wrote of bass in fish cultural ponds: "Gravel for nest building is not necessary since the largemouth is just as likely to build a nest on the bare bottom just beside a pile of gravel as on the gravel." To this he adds: "Clumps of turned over soil are not infrequently used as nests. In this case no excavation is made; the eggs are simply scattered over the roots. In ponds with excessively soft and muddy bottom, the largemouth will use the gravel and it would be wise to supply the gravel in such cases. In ponds the northern smallmouth will spawn under the same conditions as the largemouth except that they require gravel

for nest building." Further study should be made to determine fully if this is a real difference between these two species.

The actual mechanics of the nest construction is fairly simple. The nests are typically circular excavations when it is possible for the fishes to work on fairly uniform sand or gravel in the absence of current. When rocks or other objects intervene the nests are correspondingly distorted from this form. As has been pointed out by Leathers (1911) and others, the depression is made by vigorous fanning movements of the tail. As these movements of themselves induce a forward resultant, it follows that the pectorals are appropriately brought into play, for backing water, to offset this. The fishes keep turning in all directions with the result that the diameter of the nest is usually about equal to twice the length of the fish. This relationship is somewhat modified by the nature of the gravel, the specific gravity of the material moved, its average diameter, etc. It might be thought that the tail of the fish points outward, pivoting on its nose as it were. Actually the reverse is frequently the case, the tip of the tail remaining at the center of the nest, roiling the sand immediately below the fish and pushing up the opposite slope as shown in Pl. V, Fig. 7. Large objects may be pulled away by means of the mouth, but this usually happens only when an object is introduced into a nest already constructed, for sites are generally selected on fairly clean bottom. Such an object may be a twig or similar object, and the nesting fish reacts to it in a manner similar to its reaction to an intruding fish or crayfish. It is suspected that this behavior is nothing but the expression of the fighting reaction, as evidenced on an object that neither flees nor defends itself. Franklin (1914) found that bits of string and other objects dropped into the nest of *Eupomotis gibbosus* would be carried to the edge of the nest by the mouth although no eggs were yet present. Half a dozen bits caused the fish to retreat and apparently build a new nest adjacent to the old one.

In addition to this behavior the nesting male on a sandy bottom more or less persistently picks up mouthfuls of sand and expels them through the gill-clefts. The function of this is not clear but it is notable that after the eggs are laid the vigorous fanning is entirely given up, as obviously it must be to preserve the integrity of the cavity and to prevent loss or burial of the eggs. At such times the oral manipulation of the parts of the nest not covered by eggs is more persistently indulged in. Not infrequently, as a result, the exposed parts of the nest, if in very still water, reveal a pattern of dimples showing where the fish has nosed into the sand.

SEX RECOGNITION AND COURTSHIP.

At other than the spawning season the sexes of the various species of Centrarchidae are usually somewhat difficult to differentiate. During the spawning season they are not exactly easy to tell apart, as compared with many other fishes, but with a little familiarity they usually can be picked on a number of differential characters. Centrarchids are capable of some color and pattern change and it so happens that the phase assumed by the two sexes at this season differs, according to the species. The male assumes his brightest livery and the female usually one that would, out of season, be associated with extreme fright. In *Eupomotis gibbosus,* for example, the female generally shows a number of dusky, vertical bands on the body. This pattern is very unlike that of the resplendent breeding male, which is shot with a variety of brilliant metallic spots and whose red opercular tip is enlarged and intensified. The pattern of the female is very like that of an immature male or a mature one that has been badly frightened. This may be demonstrated by confining two males. If there is some fighting the loser is at once evident by his "female" pattern that usually reaches its

height in three or four days. The philosophical implications of this will be considered in the subsequent discussion.

In the breeding male various pigmented areas become intensified, as already mentioned for *Eupomotis gibbosus*. In *Lepomis auritus* the reddish tinge of the pectoral region becomes prominently brighter, the black edging of the anal and ventrals and the red eye of *Ambloplites rupestris* become intensified, and so on.

Although these differences are evident to the trained human eye, the question of their significance to the fish is not easily settled. Apparently the only observations attempting to illuminate the possible significance of these differences to any centrarchid other than the present are those of Noble (1934). He worked with *Eupomotis gibbosus,* and the present author chiefly with *Lepomis auritus,* and although there is complete agreement as to the behavior of the fishes the inferences based thereon are not, as has already been indicated by Breder and Coates (1935a).

In *Eupomotis,* Noble (1934) found that males would attempt to mate with a variety of objects, irrespective of their general appearance, provided they were so manipulated as somewhat to resemble the actions of a female ready to spawn. In *Lepomis auritus,* as well as *Eupomotis gibbosus,* similar results were obtained by the author at Llewellyn Lake. They may be best presented by giving the definite experimental results.

A piece of ordinary heavy gray cardboard cut into an oval about the size of the sunfish studied was attached to a long thin steel rod. With a little practice this could be moved about under water in a quite lifelike manner. The following experiments summarize the results obtained.

1. The model was moved toward a brooding sunfish on its nest in a manner intended to resemble the approach of another fish. When within about twelve inches of the nest the occupant would always rush toward the object. If held still the fish would bite the cardboard about half the time, and the remainder of the time would rush back to its nest, later returning—again and again—either to bite or simply to swim close to the intruding cardboard.

2. Similar to (1) except that on the approach of the guarding sunfish the model would be rapidly backed off. This resulted in a short chase of perhaps as much as five feet, which greatly resembled the pursuit of other fishes. No biting occurred, as the pursuer never caught up with the model. If the latter was moved slowly the fish followed more slowly, apparently satisfied to keep the intruder moving.

3. Similar to (1) except that the model was moved forward in the face of the nester's attack. In such cases the fish backed into his nest, sometimes with further attack, but usually without. As nearly as such things can be understood it seemed that this unaccustomed behavior on the part of the model resulted in "confusion" on the part of the nest owner. The final result was a backing off of the owner to a considerable distance where he rested until the cardboard was removed or caused to "swim away." This behavior was apparently identical to that induced by fright, such as too much disturbance on shore.

4. Similar to (3) except that the model was tilted over at an angle and the hand holding the rod mildly shaken, thus transmitting a quivering motion to the submerged cardboard. This was done with the model on the nest, but before the male had retreated. As much as possible, the model was made to "swim" in a circuit about the nest at the same time. This resulted in the fish swimming up beside the quivering model and giving evidence of trying to spawn with it.

These experiments concur completely with the views already set forth by Noble (1934) to the effect that sex recognition on the part of the male is based on the differential behavior of the female ready to spawn.

The male brilliance is considered in another connection in the section discussing protection of the nest and young. Noble (1934) writes that since the male sunfish are conspicuous and that "movement of bright objects arrests attention" of laboratory fish, "it is probable that a true sexual selection may occur in the sunfish since the females would presumably move into the redds which attract their attention first." Breder and Coates (1935) objected to this on the basis that "such a condition would appear to be valid only in the case of a large disparity between the number of males and females. Thus, a relatively few females, if mating with the first available males (on the average, most conspicuous) might become exhausted of roe before all nests received a quota of eggs. Observation by one of us in a scattered variety of places, over a number of years, leads to no such conclusion, however, since what may be called 'bachelor' males have never been noted and the proportion of the sexes is certainly not low on the female side." Actual figures given under the heading "Sex Ratio," show the sexes to be near equality. Also, as pointed out previously, unspent females may be found at the end of the season but as yet we know of no finding of unspent males at such a time.

Fish culturists find that it is advisable to stock breeding ponds of the black basses with an excess of females. Such results in a greater production of fry, see Wiebe (1935). On the other hand, he writes "The use of more males than females often leads to fighting among the males." This is understood to result from the greater activity induced by the continual failure to find a fish that will enter their nests to spawn, which culminates in more and more intensified activity of the normal sort on the part of the unsuccessful males. From various observations it seems that a fish gyrating over a depression is the signal for a female ready to shed her spawn. Such places sex recognition, on the part of the female, also on a basis of behavior. As discussed under "The Spawning Act" the unmated males become more active in proportion to their failure to attract a female, a feature which tends to insure a uniform distribution of eggs and surely overides any possible effect due to small differences in visibility between one male and another.

There can be no doubt that the females enter the nests of their own volition. On watching various species it is hard to avoid the impression that the male interferes with the entry rather than helps it. His attacks and defensive opercular spreading in response to a variety of stimuli would simply seem to be overridden by a female bent on spawning. Noble (1934) has already emphasized the importantly active role the female plays. After the entry has once been made, barring untoward events, the two fish circle about together, which generally leads rapidly to spawning.

THE SPAWNING ACT.

In all the centrachids known, the female reclines to one side for the purpose of spawning. A typical position for *Ambloplites rupestris* is shown in Pl. III, Fig. 4. Sometimes if the female is very small, about half the size of the male, the former may be in quite a horizontal position and as viewed from above may be nearly hidden from sight.

The minute details of the spawning of the above species have apparently not been recorded. Consequently the following description of it may serve as an example of centrarchid reproduction, as well as a record of what is known of the reproductive habits of this species.

Observations and notes on the reproductive habits of *Ambloplites* have been published by Wright and Allen (1913), Bean (1903), Jordan and Evermann (1903), Tracy (1910), Hay (1894), Smith (1907), Bensley (1915), Hankinson (1908), Adams and Hankinson (1928) and Evermann and

Clark (1920). The present writer has not had the good fortune actually to witness the details of spawning of this species in a feral state. The Aquarium observations herein discussed agree very closely with the field studies of others, especially with those of Bensley (1915) who wrote of the nest as follows: "It is prepared by the male fish which usually works most energetically, fanning out the sediment with his fins, thus making a basin-like depression, clean of all debris, and of eight or ten inches in diameter. The female is driven into the nest and is carefully guarded until the deposition of eggs is accomplished. During the process of spawning and fertilization, the two fish lie side by side in the nest. Only a few eggs at a time are extruded, and at each period milt is extruded by the male. The operation continues for an hour or more, and at the end of the period the female leaves the nest and does not return. The eggs are carefully looked after by the male, which takes up a position over the nest, and every now and then sets up a fanning motion with the fins. In a few days after the eggs are hatched, the fry gradually rise out of the nest and are soon left by the male to shift for themselves."

Bottoms covered with coarse gravel are usually resorted to by the rock bass for spawning, but other items will be used when necessary. Hankinson (1908) describes them spawning among bulrushes. Spawning occurs at Ithaca, New York, from April to June, according to Wright and Allen (1913), and from May 15 to June 15 in Lake Maxinkuckee, according to Evermann and Clark (1920).

The description of Bensley (1915), quoted above, is close to our observations in aquaria and aside from a few remarks little need be added. Chief among these is that in the process of spawning the female reclines on her side and the male remains upright, as is shown in Pl. III, Fig. 4. This habit, as previously mentioned, is quite characteristic of the family and has been described for *Eupomotis gibbosus* by Leathers (1911) and for *Micropterus dolomieu* and *Aplites salmoides* by Reighard (1906). Other species are described under specific heads. Probably the entire family spawns in this type of position. The details of spawning are given below in chronological order.

July 11, 1933. Two males of *Ambloplites rupestris* were noted to have eggs in one of the large exhibition tanks of the New York Aquarium containing about sixteen of the same species. One was near the back of the aquarium and the other near the glass. The latter is shown in Pl. III, Figs. 3 and 4, Pl. IV, Fig. 5. In other years, when these same fish were in smaller tanks or living in company with other and more numerous fishes, no reproductive activity was noted. In 1927 (Breder, 1928) these fishes were no more crowded than this year and then showed reproductive activity. The floor of this aquarium is composed of concrete in which partly protruding pebbles are embedded. Consequently not much of a "nest" could be constructed, but the males had removed all sediment and detritus, leaving an area of nest size of a lighter color than the surrounding tank floor. To both the pebbles and the concrete between them, eggs could be seen adhering. Mr. H. E. Dixon, in charge of these fishes, reported spawning activity up to about 9:00 A.M. Figs. 3 and 4, Pl. III, were taken this day.

July 15. The males still fanning eggs. A female with a protruded ovipositor attempted to mate with the male near the glass. The ovipositor was distinctly red and very blunt, about as large in diameter as long. The behavior was at first very like that of *Aequidens* described by Breder (1934). She quivered considerably and the two fish performed a peculiar rocking motion in a head-to-tail position. This male did not pursue the female but continued with little interruption to fan the eggs he was already guarding. The male remained in the darkest phase and the female took on a light one with faint vertical bands. Unfortunately, these color differences do not seem

to be of photographic quality. The female dragged her ovipositor over the smooth pebbles and stroked it with the tip of her ventral fins, but no eggs appeared nor was there any spawning activity on the part of the male. This activity was very like that described for *Aequidens* in the latter part of its spawning, Breder (1934).

Such activity continued for several hours until about 3:00 P.M., when spawning occurred. Pl. III, Fig. 3, shows the fish just at the finish of one of the "rocking" periods and Pl. III, Fig. 4, the actual spawning a little later. The photograph and earlier discussion of the mating position clearly mark the most evident difference between centrarchid and cichlid spawning acts. Pl. IV, Fig. 5, shows the male, after the female had left, in a characteristic "warning" attitude in response to a tap on the glass. The earlier eggs, supposedly laid on July 11, could be observed hatching while this spawning was in progress.

July 17. The male on this date was guarding two groups of eggs alternately. These, though close together, were clearly separate. The young, which were hatching on July 15, were not to be found. It is thus clearly apparent that the males of this species are capable of spawning at least three times over a short period (with as many females, or the same one?). Also a male may guard two "nests." This, however, may be a condition imposed by the hard bottom where no true nest cavity could be excavated.

July 20. The activity was all over and the males (both) relinquished their guardianship. No young could be found. It may be noted in passing that these males were very active in driving off a few large *Cambarus* kept in the aquarium as scavengers. These crustaceans would repeatedly attempt to reach the eggs, only to be driven off when they got within about an inch of them. It seemed the fish recognized the power of their chelae and were satisfied to rush at them to a point not quite within striking distance. This was sufficient, however, to cause the crayfish to back up and put on a considerable display of defense. As soon as the fish withdrew, the *Cambarus* would again attempt to reach the eggs. This seesaw might go on for an hour at a time before the latter would eventually withdraw.

In the summer of 1934 a pair was placed in a small laboratory aquarium. Almost immediately the male excavated a nest that occupied practically the entire floor of the tank. This is shown in Pl. IV, Fig. 6. This illustration seems to show the type of nest constructed when a uniform bottom is provided and that it is essentially similar to those of other species, as well as the fact that confinement in small space is not a deterrent to nesting, although as previously stated crowding must be so considered. This figure also illustrates the most prominent secondary sex characters; the dark edged ventrals of the male and the white edged ventrals of the female. The dark edging of the male anal fin is not usually as clear cut a sexual difference as this particular pair would suggest.

Noble (1934) thinks that the female is in control of the spawning operation. With this we are in complete accord and indeed it may be considered as a general condition in fishes, since the expulsion of eggs is usually dependent on the internal organs of a freely drifting object that may or may not be able to do on the stimulation of the male. Whether there is a male orgasm or not is without biological significance unless the eggs are present. While observations on sunfish have never been sufficiently close range to be sure of such, it certainly happens in other fishes. For example: in *Ameiurus nebulosus,* pair "B" of Breder (1935), in the summer of that year, following publication, observations were made that such happened repeatedly before the female was able to release her eggs.

After the eggs are deposited the female leaves at once. Many females may visit one nest and one female may visit many nests. In fact, close observation of *Eupomotis gibbosus* showed that nearly every nest in a small

colony may be visited by one female. Since sunfish nests usually occur in colonies and with the habits of the females above mentioned it follows that the significance of sexual selection cannot be of any particular importance, even if one especially bright male happens to attract females first. Furthermore, it has been repeatedly observed that the males become agitated on the appearance of another fish and the increase in their activities certainly makes them more conspicuous. A lone male on a nest adjacent to one containing a spawning pair, because of his evident excitement is frequently the most conspicuous object on the entire bed.

Under normal conditions the Centrarchidae seem always to mate in pairs. Abnormal circumstances may lead to a simultaneous polygamy, however, as witness the following experiments: One male and three females, *Eupomotis,* were placed in a large aquarium in the expectation of spawning. The male constructed a typical nest, Pl. VI, Fig. 9, and spawned repeatedly with one or another of the females, as was to be expected, Pl. VII, Fig. 11. On one occasion three fish were found in the nest; the male in the middle of the group with one female on either side, reclined at nearly 90° and all headed in one direction. Eggs were extruded and apparently all three took active part in the spawning. It would seem that under these controlled conditions, with a dearth of males, that two females becoming egg-burdened simultaneously accounts for the phenomenon. Probably if another nesting male had been available such an occurrence would not have taken place. These four fish were left in the aquarium throughout the following winter at laboratory temperature (24°C.). On December 26 the male started excavating a nest that soon took on the typical form. Pursuing of females was still going on at this writing, January 30, but no spawning took place. It is thus evident that the advent of the reproductive season may be considerably advanced by the maintenance of a continued high temperature.

PROTECTION OF THE NEST AND YOUNG.

After the female has deposited her eggs her role in the perpetuation of the species may usually be considered finished. The value of incubation of the male parent is relatively clear. The fanning motions of the pectoral fins prevent the eggs from being suffocated under a layer of silt. They are not necessary for aeration, as these eggs hatch excellently in aquaria of standing water, *Eupomotis, Lepomis* and *Enneacanthus* all having been so hatched by the author. The protection of the parent against predators is certainly important, as described for *Ambloplites* in regard to crayfish. Greeley (1934) describes the behavior of a male *Lepomis auritus* in defending its nest against others of its own species. By the simple expedient of catching the male by hook and line he showed that this defense is necessary, for on capture, he writes: ". . . the small sunfish quickly appropriated the nest, mouthing the stones greedily to get the eggs." From this he concluded that "Nest defense of the male is clearly necessary to protection of young in this and related species."

This item of reproductive pattern is practically identical with that of the cichlids (Breder, 1934). The male, however, is the only attendant on the sunfish nest. In spite of the large literature on sunfish nests there are few observations recorded in which both sexes may have taken part in protecting the eggs. Fowler (1923) states of *Lepomis auritus* that he found a nest guarded against an active horde of minnows by "both parents, or at least two adult fishes," and that "This is the only case I know of where two sunfish were actually seen guarding one nest." In reference to *Eupomotis gibbosus* he wrote: "Sometimes the female is said to assist the male in the care of the nest, though I have never noticed this solicitude. Quite likely the female seen on the nest with the male in most cases may be

incidental." We may add to this the observation on both species that all cases that had at first seemed to be this sort of behavior developed to be a female looking for a nest in which to deposit her spawn, as was subsequently established. Care by both parents has been described for *Aplites salmoides* as exceptional behavior, by Smith (1907) and by Hankinson (1908).

The protection of the nest against larger fishes is a truly remarkable performance. On one occasion a rather small *Lepomis auritus* was seen to rout and chase for some distance a much larger *Aplites salmoides*. The larger fish could easily have swallowed the defender in one gulp, but it literally turned and fled when the sunfish dashed at it. The much larger *Aplites* so completely outdistanced the *Lepomis* in a few strokes of its tail that the "pursuit" immediately became a farce. The psychological attitude of the two fishes under such circumstances is not too clear but it would seem to have to do with territory and proprietorship, which appears again and again under different guises. It is well known among aquarists that a fish well established in an aquarium is almost certain to dominate subsequently introduced fishes even if the latter are larger and even when there is no reproductive activity. Presumably, this was the cause of the attitude observed by Nichols (1918) on the part of two porgys in which one "had a bullying attitude and the other one a cringing attitude." See Breder (1934a) for remarks on a number of species regarding nesting territory and Evans (1936) for similar data on a lizard.

Care of the young is not as strongly marked in these fishes as in various other families, but there exists a certain amount of such activity for a short time. It is probably best marked among *Aplites* and *Micropterus* and has been recorded in the former by Reighard (1906), Smith (1907), Bean (1903) and Richardson (1913). The author noticed extremely vigorous activity in an *Aplites* protecting a well-formed school from other bass in Byram Lake, New York. Reighard (1906) describes similar behavior on the part of *Micropterus dolomieu*. Such activity as exists in the Centrarchidae seems to be very similar to that shown by some cichlids.

Continued and extensive yawning is an accompaniment of egg protection in numerous species of fishes. The yawn in *Monocirrhus* Coates (1933) thought to be a defensive gesture due to the extreme change in appearance that this movement produces in the species and which he figures. Breder (1935a) suggested that in *Ameiurus* this activity might have to do with aeration. It is also common in the Centrarchidae, see Pl. V, Fig. 8. These fish have neither an horrific appearance when yawning, due to their relatively small mouth, nor can such a movement by any stretch of the imagination be construed as having an aerating function. It is true that usually they can all be induced to do it on a not too frightening disturbance, and it will be done as soon as nest construction is well under way, even before eggs are laid. It would seem best at the present to consider the phenomenon to be of some unknown physiological import that takes on other values dependent on the morphology of the fish, the position of the eggs, their needs, etc., so that in some forms it may be of "threatening" value and in others of aerating significance to the eggs, as well as possibly other functions in species as yet unstudied.

SEX RATIOS AND NATURAL HYBRIDIZATION.

Since the Centrarchidae represent a rather closely related group of fishes, with frequently several species living side by side and resorting to the same places for reproduction at about the same season and even going so far as to usurp each other's nests, it is perhaps not surprising that hybridization should occur naturally. Hubbs (1920) and Hubbs and Hubbs (1931), (1932) and (1933), have established the fact of this phenomenon and as a result have been able to reduce a number of nominal species to

the status of hybrids. While a discussion of their work is outside the province of the present paper, many of the items of reproductive behavior herein mentioned give a background against which this extensive natural hybridization rests. To state it another way, there is probably no group of fishes, North American at least, in which there would seem to be a concatenation of reproductive and other events so well arranged as to lead to extensive hybridizing; *i.e.* the species are numerous; there is less geographical separation than usual; spawning occurs at about the same temperature threshold; spawning sites are limited and similar for most species; nests are exchanged among species. Thus far Hubbs has recorded hybrids between the following forms:

Chaenobryttus gulosus	X	*Apomotis cyanellus*
	X	*Helioperca macrochira*
	X	*Eupomotis gibbosus*
Apomotis cyanellus	X	*Xenotis megalotis*
	X	*Helioperca macrochira*
	X	*Allotis humilis*
	X	*Eupomotis gibbosus*
Lepomis auritus	X	*Eupomotis gibbosus*
Xenotis megalotis	X	*Helioperca macrochira*
	X	*Eupomotis gibbosus*
Helioperca macrochira	X	*Eupomotis gibbosus*

The sex ratios of these hybrids, including laboratory reared material, Hubbs and Hubbs found to be predominantly male, 81 to 95 per cent. In such non-hybrid forms as have been examined the sex ratio is normally about 1 to 1. Figures given by Hubbs and Hubbs (1933) and Hubbs and Cooper (1935) follow:

	Male	Female	% Male
Apomotis cyanellus	217	192	53
Xenotis megalotis	605	491	55
Eupomotis gibbosus	218	241	47
Helioperca macrochira	125	116	52

Even this slight bias to maleness may be due to collecting methods, which Hubbs and Cooper suggest. Reid (1930) also found the sexes of *Eupomotis gibbosus* to be in about equal numbers. Fish culturists find that the most successful ponds for the breeding of the three black basses are those in which the females are in excess.

In this connection it may be pointed out that these hybrids were always found to be sterile, although males sometimes built nests and attempted breeding. Hubbs and Hubbs (1933) wrote that an "indication of the unnatural sexual behavior among *Apomotis* X *Eupomotis* hybrids was exhibited by an aquarium-bred individual which played the part of a female in an attempted mating, vigorously taking the initiative in the female nuptial behavior. Yet a superficial and histological examination of the gonads of this fish showed it to be a male." Aside from the fact that this is probably the first record of homosexuality in fishes it is of considerable interest to note that this fish, in spite of its male gonads, imitated the female act when in the appropriate "psychic" attitude. They continue as follows: "One of the few females of this same combination which we have been able to keep under observation repeatedly dug nests and otherwise played the part of the male in nesting and mating behavior. A male *Apomotis* X *Helioperca* behaved as a female."

ANNOTATED SPECIFIC LIST OF HABITS.

The treatment of the reproductive features of the Centrarchidae in the present paper has been that of considering the various items of behavior as a whole and illustrating specific points with data on particular species, mostly based on original observations. This method was pursued because of the essential uniformity of the group. It remains now to consider and compare the known data on each of the twenty-five species recognized today.

The classifications followed and species recognized are based on the tentative opinions of Dr. C. L. Hubbs who kindly gave his views on the taxonomy of the group, which he emphasized as "extremely tentative," in a personal communication.

Micropterus dolomieu Lacépède.

The small-mouthed black bass, because of its interest to fish culturists and anglers, has been discussed in regard to reproductive habits by a large number of students. The author can add nothing to the data already published by these numerous writers. Apparently throughout its range *Micropterus* is the first to spawn with the coming of spring, *Aplites* being the only other genus at all approaching it in time and temperature. Beeman (1924) gives 64° F. as the spawning temperature and 60° as an inhibiting level. Reighard (1906) gives 62° with the very beginning of nesting below 60°. Nash (1908) gives May to July as the spawning months in Ontario and Tracy gives as early as March for New York State. The earliest date noted by the author (Kensico Reservoir) is May 26, with a temperature of 64° F.

According to Wiebe (1935), "Most of the spawning by the smallmouth occurs probably at 62° to 64°." Tester (1930) describes one nest with eggs at a morning temperature of 55.4°.

According to all observers, nest building is typical for the group, Reighard (1906), Beeman (1924), Adams and Hankinson (1928). The depth of water according to Beeman is from two to twelve feet, Forbes and Richardson (1909) about three feet, and Evermann and Clark (1920) about six feet. The author found them nesting in Kensico Reservoir at depths of about three feet, at Byram Lake in less than two feet, and in Lake Gilead in depths considerably in excess of twelve feet. This latter lake is exceptionally clear and visibility to at least twenty feet is perfect.

The nest, as in other species, has a diameter roughly equal to twice the length of the fish, Wright (1892). As previously indicated this varies considerably with the type of the bottom. Beeman (1924) gives two to four feet for the diameters he found. Forbes and Richardson (1909) write that the construction may take from four to forty-eight hours. This may be greatly prolonged, however, if cool or cloudy weather intervenes. Cheney (1897) found that nest construction stopped if the temperature fell below 65° for long. Thus the breeding, as with most spring reproduction in fishes, occurs earlier in the southern part of the range. After spending the winter in a semi-dormant state in deep water, they approach shallow water and there appear to be no other migrating movements, according to Bensley (1915). The grounds resorted to are usually some gravelly spot along a lake shore which may vary from two to twelve feet in depth with about three feet as an average. Sometimes patches of vegetation are resorted to, according to Beeman, which probably is associated with a lack of more suitable sites.

The male alone engages in the nest building. After a suitable spot is selected the bottom is cleared of all loose material. This is done chiefly by rooting and by means of mouth, aided by fanning motions of the fins, according to Reighard (1906). When the nest is once constructed the male awaits a female and makes short rushes at her when she appears. These

may be found close by, seemingly awaiting the courtship procedure. According to Beeman (1924), this may happen repeatedly, the female remaining on the nest a little longer each time. At the actual spawning sexual dimorphism is distinctly evident. The pattern of dark marks on the body of the female becomes very distinct as the underlying ground color fades to a very light tint, according to Adams and Hankinson (1928), quoting Reighard (1906): "When the female is finally ready to spawn, there is a marked change in her appearance. The dark mottlings on her body become very prominent, due to the ground color becoming much paler than usual. It is only at the spawning time that there is a prominent sexual difference as to colors. But close observation will show a red spot on the iris of the male, which is not ordinarily present in the female." Also, "during sexual excitement the female may appear much darker than the male."

The actual spawning may be quoted from Adams and Hankinson (1928) as follows: "During these changes the female swims slowly in a circle or floats motionless, and every two or three minutes rubs her belly against the stones with a deliberate bending of the body to one side and then to the other, and the male bites the female frequently though gently, on the opercle, cheek and corner of the mouth. This act is interpreted by Reighard (*l. c.*, p. 20) as a stimulus for the emission of the eggs. During the emission of the eggs, to quote Reighard: 'The two fish lie side by side on the bottom. The female is turned partly on her side so that her median plane forms an angle of about 45° with the plane of the horizon. The male remains upright with his head just back of the pectoral of the female or opposite it.' The male is quiet during the process while the female exhibits certain peculiar fin movements. The eggs are emitted at periods when the female is with the male in the nest. Reighard (*l. c.* p. 12) noted four such periods occupying from four to six seconds each and separated by periods of about 30 (22-45) seconds. The female he observed remained two hours and twenty minutes with the male in the nest, and when she departed the male pursued her, but returned to care for the eggs, which meanwhile had become adherent to the bottom stones of the nest . . .

"The male readily pairs with another female that may approach the nest, the eggs being deposited with those already laid. Beeman (*l. c.*) noted that the time in which the male shows a disposition to spawn with different females varies from 30 to 36 hours; and that he appears to be able to fertilize the eggs of at least three females.

"A female may spawn in more than one nest (Reighard, '06, p. 12). Ordinarily a male spawns with but one female at a time, but Beeman ('24, p. 99) describes a case of a male spawning with two females in the same nest at the same time, with an alternation of the egg-laying periods, and both females leaving at about the same time after their eggs had been laid.

"Beeman ('24, p. 98) mentions males fighting over females, and such fighting ensues generally when there are too few females to the number of males in a breeding pond. Lydell ('04, p. 42) also notes fighting of male fish especially when nests are close together, as they are likely to be in a small body of water, and gives an instance where a male was killed and its nest destroyed by the attack of ten or more other males." See also Lydell (1926) and Wiebe (1935) on numbers of pairs and sex ratios in relation to size of hatchery ponds.

The incubation period varies from seven to sixteen days according to Langlois (1932), varying chiefly with water temperature. At 59° to 60°, according to Beeman (1924), incubation lasts twenty-one days. Lydell (1904) gives six days at 60°. Tester (1930) found that if the temperature is raised from 61° to 73° just before the hatching time, the eggs will not survive.

The spawning and parental care exhibited by the male is described by Adams and Hankinson (1928), Bensley (1915), Cheney (1897), Evermann

and Clark (1920), Forbes and Richardson (1909), James (1930), Lydell (1904), Moore (1925), Tester (1930) and Wright (1892).

The first mentioned write: "The male guards the eggs until they are hatched. If another fish approaches too near he attacks it, and, according to Reighard's observations, the intruding fish will invariably flee." This agrees with the present author's observations on this and other species, in fact with practically all species of nest building fishes.

The newly hatched fish lie on the stones of the nest for some time but rise with apparently one accord. After this time the male herds them together as they weave about in a dense school, very much after the fashion of cichlid behavior analyzed by Breder (1934a). Probably the same methods of control are employed, even to the feature of causing the young to descend to the bottom by means of suitable fin manipulation. Although the author cannot claim to be certain of this, Howland (1931) indicates that such is the case.

Micropterus pseudaplites Hubbs.

The reproduction of this species, according to Howland (1932), is very like that of *M. dolomieu*. He mentions having observed a male removing pebbles for the nest by oral means. Also that in the spawning act the male circles to the outside, which is probably true for the whole family. Viosca (1931) writes: "The breeding habits of the southern smallmouth seem to be essentially like those of its northern congener. It spawns on gravel bars in the spring, but in South Louisiana, later than the largemouth." Howland (1931), who had the species in fish cultural ponds, wrote as follows concerning the parental care of three males: "The male bass does not make moves to conduct the school of young fish. As soon as the fish are hatched he moves off of the nest remaining in the immediate vicinity, but not over the nest. He does not beat the young fish down by the movements of his fins as does the small-mouth. The male was observed to leave the fry at different times. In one case he left them when they were about five days old, while in the other two cases he stayed with them until they became approximately a half-inch in length." Wiebe (1935) mentions that in fish cultural practice twice as many females as males produce good results.

Aplites salmoides (Lacépède).

Spawning occurs in spring about the time or even a little earlier than that of *M. dolomieu*. Shallow waters are resorted to and the nest may be constructed in from six inches of water, Richardson (1913), to about six feet, Evermann and Clark (1920), but they tend to average probably about two feet.

The water temperature at the time of nesting, so far as the author's records go, is 70° F. (Kensico Reservoir) which is in late May in shallow bays warmer than the main body of water. Most observers seem to have contented themselves with dates: Forbes and Richardson (1909), May and June, Illinois; Richardson (1913), April 26 to May 18, Illinois; Evermann and Clark (1920), May 15 to 30, Indiana; Tracy (1910), April to May, Rhode Island; Bean (1903), April to July, New York; Bensley (1915), early June, Georgian Bay; and Hankinson (1908), May 16, Michigan. But as Adams and Hankinson (1928) point out, "Much has been written on the life histories of black bass, but the two species are often treated together, which is unfortunate since there are evidently important distinctions between the two as to breeding." Other data is given by Lambkin (1901) and Langlois (1935).

Wiebe (1935) writes: "Wild bass from the Mississippi River, were placed in a pond on May 16. These fish were seen on the nest the following

day. On May 23rd, eggs and fry were removed from several nests. The fry were not observed on the surface until May 30th. The temperature during this period ranged from 65-73°F. at 8 a.m. and 69-82°F. at 5 p.m. It is generally assumed that the large-mouth do not spawn at temperatures much below 64°F."

The bottom selected may be gravelly, sandy or covered with dead leaves or trash. The following description is quoted from Adams and Hankinson (1928): "The nest is a simple affair, usually difficult to locate, and many times can be found only through the behavior of the fish guarding it. Reighard ('06, p. 15) says: 'They are much less conspicuous than the nests of the Small-mouth Bass and are usually less excavated. Often the bottom is covered with dead leaves, fallen from neighboring trees, and the fish has merely swept away the thin layer of ooze from these and the eggs have been laid upon them. In other cases the roots of low growing shoots of water plants have been similarly cleaned. Sometimes an area of sandy gravel has been swept clean, but has not been hollowed out nor has the sand been removed from among the pebbles. All such nests are inconspicuous and are usually found only by first observing the presence of the male bass. In but one case have I seen a Large-mouthed Bass on a nest that was well hollowed out and in which the sand had been removed from among the pebbles at the center of the nest. This was, however, in a pond in which Small-mouthed Bass were also present, so that the work may have been in part that of a Small-mouthed Bass.' Evermann and Clark ('20, p. 417) describe the nests as circular depressions filled with pebbles from about the size of a hen's egg down, and the nests as about 2½ feet across. Hankinson ('08, p. 214) describes the nests found at Walnut Lake as circular masses of blackened bulrush roots. Bensley ('15, p. 41) says, 'The fish construct nests, by fanning out huge basins with the fins, sometimes three feet in diameter and a foot into the bottom.' Nash ('08, p. 89) also describes the nests as made by scooping out sand and mud. Richardson ('13, p. 414) found the nests to be well-excavated, nearly round (12-18 in. across) and with grass roots at the bottom. Forbes and Richardson ('09, p. 268) say that the nests are built by the males among fallen leaves or fibrous rootlets in sand or gravel."

The inconspicuousness of these nests has not been noted by the present author and the differences are believed referable to the types of bottom available. In Kensico Reservoir the nests of *Micropterus* are generally less evident than those of *Aplites*.

The description of the spawning act and parental care is quoted from the same authorities: "Spawning has apparently not often been observed, which may be due to its taking place at dusk, according to Reighard ('06, p. 15) who gives an account of spawning in artificial ponds near Grand Rapids, Michigan. The female in this case was somewhat darker colored than the male and had a more distended abdomen. 'The male was in the nest or near it and repeatedly the female approached. The male circled to her outer side and bit her flank and she then went away. Three or four other bass, probably males, were seen ten or fifteen feet outside the nest. I returned at 7 P.M. and found the same conditions. The female was seen to approach the nest and to turn on her side with her head pointed obliquely downward and to float thus, as though half dead. In this position she entered the nest and the male followed and took up a similar position. What happened in the nest could not be clearly seen. The tails of the two fish could be seen and from their position it was clear that the fish lay side by side on the bottom with their tails together and parallel. It could also be seen that sometimes one and sometimes apparently the other fish lay turned partly on its side. At this time no doubt the eggs were emitted. After being in the nest for a short time the fish came out, and the female was seen to be still floating, head downward. They then returned to the nest and continued thus for half an hour, alternately lying on the bottom

within the nest and floating on its border. It was then too dark to make further observations.

" 'That the male of the Large-mouthed Bass habitually receives more than one female into his nest or receives the same female a second time after a considerable interval is shown by the fact that in three nests in which the eggs were examined in their earlier stages some were found that had been recently laid and others that had been laid for forty-eight hours.' Forbes and Richardson ('09, p. 269) hold that the male seeks the female and that the spawning is intermittent. The eggs are adhesive and several thousand are laid by one fish (Smith, '07, p. 247; Lydell, '04, p. 40). They adhere to roots, stones or other objects in the nest bottom. They hatch in 8 to 10 days, according to Forbes and Richardson ('09, p. 269), but Reighard ('03b, p. 15) says the eggs are hatched usually at the end of three days. They are guarded by the male and sometimes by both parents (Smith, '07, p. 247; Hankinson, '08, p. 214). The young are also attended by the fish during the time they are in and about the nest (Reighard, '06, p. 16; Smith, '07, p. 247). The young may remain in the nest a week or ten days (Bean, '03, p. 492). After leaving it they swim in compact schools. Richardson ('13, p. 415) noted 6000 young in two schools."

This apparent spawning in weak light is certainly not typical of the generality of Centrarchidae.

Chaenobryttus gulosus (Cuvier and Valenciennes).

The warmouth is reported as breeding in Illinois in June by Hubbs (1919). The nest he described was fifteen feet from shore in about three feet of water.

Apomotis cyanellus (Rafinesque).

A green sunfish, discussed by Hubbs (1919), is described as building no nest at all but attaching its eggs to willow roots. It is hardly likely that this is normal for such a fish but that it represents a badly built nest similar to numerous others described herein. Hubbs and Cooper (1935) show that the males are generally larger than the females and spawning takes place from late June to August in Michigan.

Sclerotis punctatus (Cuvier and Valenciennes).

Apparently there is no data at all on this species.

Lepomis auritus (Linnaeus).

Considering the abundance and wide distribution of the redbreasted sunfish it is surprising that there are not more references to it in the literature than appears to be the case. In the vicinity of New York its conspicuous nests vie with those of *Eupomotis* in abundance. Nests have been found from June 6 to as late as August 12 at temperatures ranging from 68° to 82° F. Fowler (1923) gives June 10 to June 25 in the vicinity of Philadelphia. Nests vary from about 10 inches to 24 inches in diameter and are found in depths of from six inches to 18 inches in depth. Fowler (1923) gives a diameter of twelve inches to sixteen inches and in a depth of water from less than a foot to about twenty inches. For more comprehensive details on the nesting of this species see Table II and Table III. Text-figs. 4 and 5, together with the accompanying text, show the extremes to which this species will go under favorable and unfavorable conditions, obviating repetition here. See also Breder and Redmond (1929), who figure a typical nest.

The nest building and courtship of this species form much of the basis of the preceding sections and need not be repeated here, as in all cases of

details the species definitely studied is indicated. The frequent association of this species with *Eupomotis* and *Aplites* leads to the complex interactions of nesting already alluded to.

The pre-spawning behavior of this sunfish has been studied by Breder and Nigrelli (1934). They indicate a primary urge to aggregate on the

TABLE III.

Nesting dates of *Lepomis auritus* in the vicinity of New York City.

Locality	Year	Pre-nesting Period	Nesting Period	Post-nesting Period	Temp. °C.
Branch Brook Park, Newark, N. J.	1913	—	June 13	—	—
	1926	—	June 6	—	20
	1927	May 11	—	—	—
Singac, N. J.	1919	—	June 30-July 12	—	—
Haskell, N. J.	1928	—	July 15-27	—	—
Pound Ridge, N. Y.	1933	—	June 11	—	—
	1934	June 3	—	—	—
Llewellyn Lake, N. J.	1934	May 20	July 14	July 28	25.5
Lake Mohawk, N. J.	1934	May 20	July 14-29	Aug. 12	25.5
Kensico Reservoir	1935	June 9	June 14	Aug. 15	27.5
Byram Lake	1935	June 9	June 14	July 6	27.5
Range of dates	.....	May 11-June 9	June 6-July 29	July 6-Aug. 15	20-27.5

part of fishes generally, except as inhibited by definite influences such as reproductive urges, etc. The definite formation of schools was found to occur, in adult material, only below 5° C.

Helioperca macrochira (Rafinesque).

The blue-gill, similar to the redbreast in habit, usually nests in similar colonies. Hankinson (1908) mentions from nine to fifteen to a colony. Spawning occurs in May in Illinois, as mentioned by Richardson (1913); in May and June in New York, by Wright and Allen (1913); in May in South Dakota by Churchill and Over (1933), and in June in Indiana by Evermann and Clark (1920). Coggeshall (1923 and 1924) gives related data. The present author has found them on nests from July 14 to 28 in Lake Mohawk, northern New Jersey, with a temperature of 76° F. Of the nesting of this species, Richardson (1913) remarks as follows: "The nests were chiefly in bunches about the bases of the willows, in some cases as many as a dozen about one tree, all in the shade, and many of them only two or three feet apart. This fish seems particular to select about the same sort of situation for all its nests—a rather hard bottom of sand and mud, with little vegetation, but with some fine dead drift, grass, twigs, etc. The nests are eight to twelve inches in diameter, usually quite round, and the excavation of the bottom soil is always well marked—usually to a depth of half an inch or an inch. . . . The males are much more shy than males of the warmouth bass, but they can easily be seen and identified on nests by approaching quietly."

The eggs of this species, experimentally immersed in sea water, were found to sink rapidly even in water concentrated to a density of 1.035 sp. g.

Xenotis megalotis (Rafinesque).

The long-eared sunfish nests, according to Hankinson (1908), in Michigan in July and in New York, according to Adams and Hankinson (1928), during the same month, and from late June to August in Michigan according to Hubbs and Cooper (1935). They describe the nests as follows: "Several nests in about a foot of water were saucer-shaped depressions like the nests

of other sunfish. The bottom here was of fine gravel, of a character different from any other bottom material in the lake for it had been hauled there for some construction work, probably as a support for a pier. The eggs were on the bottom stones. An adult male in gaudy breeding dress guarded each nest, and small companies of females were moving about in the vicinity. All of the nests were found on this patch of gravel, except one, which was in Milton Point Bay, about a mile northeast of this place. This one exception was situated close to the shore and was similar to the nests found at Brewerton. A male was guarding it, but no eggs could be found. All of these nests were found on July 25, 1916. The attending males were not quite four inches in length; the females were decidedly smaller, nearer three inches long."

According to Hankinson (1908), the eggs may be attached to the roots of plants after the latter have been cleaned of bottom mud. Hubbs and Cooper (1935) show that the males grow faster and generally reach a larger size.

Allotis humilis Girard.

A detailed study of the orange-spotted sunfish is given by Barney and Anson (1923) from which the following is drawn. Sexual differentiation during the reproductive period is well marked, the males being even more vividly colored, in a complicated pattern, than in most sunfishes.

The spawning season begins in Louisiana near the first of April and extends to September and in Iowa from late May to August, when the temperature reaches about 65°. The younger fish nest later and thus account for the long spawning period, a condition probably true for the entire family. The nests in soft bottom measured from 15 to 18 cm. in diameter in a depth of from 12 to 36 inches of water. In Louisiana, with only a mud bottom, apparently no distinct nest is formed. Females were found with up to 4,200 eggs. Exceedingly large colonies were found by Barney and Anson, one having 960 nests on a bank 365 feet long and of only a few feet in width.

Lethogrammus symmetricus (Forbes).

Apparently there have been no data recorded on the reproduction of this species.

Eupomotis gibbosus (Linnaeus).

The common sunfish spawns in late spring or early summer. Abbott (1884), Gill (1907), Hankinson (1908 and 1909), Forbes and Richardson (1909) and Wright and Allen (1913) place nest building in May and Bensley (1915) and Leathers (1911) up to August. Spawning has been observed in June and July by Hankinson (1908), Leathers (1911) and Embody (1915). As indicated in Table IV, nesting about New York City extends from May to July. Activities in aquaria are described by Becker (1908). Wild nests are figured by Breder (1926) and Breder and Redmond (1928) and discussed by Krecker (1916) and Myers (1921).

The nest is usually constructed in less than two feet of water, generally in quiet ponds, lakes or creeks. Extensive details are given in Tables I, II and IV, Text-figs. 1, 2 and 3, Pls. I, II, Fig. 1, 2 and V-VII, Figs. 7-12, inclusive, with their accompanying discussion. The bottom may be of clay and gravel or sand but shows considerable variation, as indicated in an earlier part of the present study. The nesting and reproductive activity quoted below is from Adams and Hankinson (1928):

"The nest is typical of the other sunfish nests in being a more or less circular bottom depression, made by a fanning movement of the tail; and objects too large or heavy to be removed by this method are pulled away

by means of the mouth (Leathers, '11, p. 252). The nests are usually as nearly circular as bottom features will permit and in diameter are commonly about twice the length of the fish. A gravid female is brought to the nest by the male, and in the spawning act the two fish apply their ventral surfaces and move about in a circle, the eggs and sperm exuding. Leathers (*l. c.*, p. 253) counted eleven circuits a minute made by spawning individuals, and found that the male remains upright, the female horizontal. Clouds of sperms intermixed with eggs could be seen emitted at intervals and at such times the female would make quick tail movements, throwing herself into an upright position."

These observations are in essential accord with those of the author except the bringing of a female to the nest by the male. The following description of difference of the sexes and the reproductive habits, also in substantial accord, are quoted from the same authorities:

"Reighard ('02, p. 575) notes that the male is brighter colored than the female, with brighter vermicular cheek markings, and with black ventral fins while those of the female are yellow; and the dorsal and caudal fins in the male a more brilliant hue. He also noted that the opercular flap in the male is larger. In many observations made on spawning Common Sunfish, Hankinson found the female usually smaller and decidedly lighter in color and less brilliant, resembling the immature rather than the adult male. Apparently it is only the male that constructs and attends the nest (Reighard, '02, p. 575; Bean, '03, p. 485). He guards the eggs against other fishes and other intruders. His boldness at this time is well known, and he goes so far as to bite hands and fingers if held near the nest. The spreading of the gill-covers and the displaying of colors appear to be instrumental in driving away intruders (Reighard, '02, p. 575) as well as in attracting the female. It has been generally assumed that this sunfish and others guard only the eggs and not the young. In this connection the observations of Evermann and Clark ('20, Vol. 1, p. 408) are of interest, with regard to a nest of Common Sunfish found July 7, 1901: 'The young were quite minute, transparent objects, the eyes being the most conspicuous part of them. They hugged the bottom quite closely, but were pretty active. Now and then one of them appeared to take a notion to leave the nest, and would swim up toward the surface. Quick as a flash the parent fish would snap it up, and it appeared at first glance as if it were devouring its young, but it was soon discovered that each time it had taken in a young fish it immediately went down to the bottom of the nest, head downward and spat the young out into the nest near the ground.' The eggs adhere to bottom objects such as soil particles, small stones, roots and sticks."

This habit of returning the young to the nest can only be considered as feebly developed in the Centrarchidae, although it is typical of the Cichlidae. Few students have seen sunfishes transporting their young by oral or other means. The author has never seen anything even remotely resembling such behavior.

Experimental studies in the sex recognition of this species have been made by Noble (1934), the observations of which concur fully with those of the present author but who does not find it possible to draw the same inferences, Breder and Coates (1935a). These differences of interpretation are considered in the discussion. The actual experimental results are mentioned in detail under the previous consideration of sex recognition. Other items in connection with this feature of behavior are as follows: At the site illustrated in Text-fig. 1 large numbers of females could be found under the shelter of the canoe dock. These would cruise out in the vicinity of the nests and be pursued by one or more males. Such attention usually drove them back to the inactive group of females, but finally after considerable play a female would enter a nest and spawning would ensue almost imme-

diately, the female inclining to one side in the typical centrarchid fashion. Other males in nearby nests could be seen to pay the strictest attention, but in no case was any attempt to interrupt the proceedings noted, once the female had definitely entered a rival's nest. The males were at their brightest and the females tended to display vertical bars, similar to those evident in immature and badly frightened fish, see Pl. VII, Fig. 11. If these differences of pattern bear any social significance to these fishes it is not evident from the present studies. On the nesting grounds, any wandering fish even of other species, such as young *Micropterus* or adult *Notemigonus,* may be pursued by males which sometimes leave their nests for considerable distances. Flight is the customary reaction of the pursued, on which the pursuer returns to his nest. The females usually perform in a similar manner but when nearly ready to spawn do not retreat so far. They return again and again and may seem to be driven into the nest by the male. The direction of "driving" appears to be determined entirely by the direction the pursued elects to follow. This view would give the role of spawning determination to the female. That is to say, the males having established themselves on a nest pursue practically anything, giving up the chase only when it leads far away from the nest. This view fuses the "fighting" and "courting" behavior into one, with the behavior of the female as the determining element. This is essentially the type of sex recognition already discussed for the cichlid *Aequidens* by Breder (1934a). Noble and Curtis (1935) believe, however, they have detected selection of males on a color basis by the females of a cichlid, but as the report is a short abstract, details are insufficient to interpret their findings. The trial and error method in the present case rather presents a clearer cut picture than in the cichlids because of the mechanical circumstances involving the construction of a nest prior to courtship.

Experiments were undertaken with sunfish in aquaria. Four fish were used; three females and one male. The male constructed a large, well-formed nest despite the fact that the aquarium was comparatively small— 3 feet long by 2 feet high by 1½ feet wide. During the construction period he prevented the others from approaching the center of the nest only by about six inches. This short distance presumably was controlled by the small size of the aquarium. The nest was started July 1 and worked on continually, but no spawning was seen to be attempted before July 5. These attempts were continued alternately with persistent nest cleaning but there were no eggs until July 17. These were hatched on July 20 at a temperature of 28°C. The spawning of July 17 started at 5 P.M. and continued for an hour. After a while a second female joined the original pair, and the three attempted (or succeeded?) in spawning together. The male was upright between the two females, one inclined on either side of him and all headed in the same direction. This irregularity in behavior has already been mentioned under the discussion of the spawning act. The young resulting from this spawning had all disappeared by July 22. On July 24 the male was again vigorously cleaning the nest and before August it was in finished condition. On August 2 young fish were again found in the nest, thus establishing the fact that these males may spawn at least twice in a season in the same nest, with the same or with other females. Typical poses of this male are given in Pls. V-VII, Figs. 7-11, in aquaria, and of one in a state of nature, Pl. VII, Fig. 12. This male again built a nest in December, the details of which are discussed in the previous general section.

Abbott (1884) wrote as follows about this species: "Each fish, wherever it may go, has some point which is recognized as the terminus of the lane leading to the nest, and having found this it speeds up the narrow pathway with incredible velocity and stops as suddenly just at or in the nest." Gill (1907) commented that "The actions noted by Abbott must be manifested only under certain conditions. I have not noted analogous in-

stances." Among all the species studied in the field, observations were made by the writer which in part confirmed Abbott's views, with, however, numerous exceptions. It would seem that the more or less immediate environment is more familiar than territory farther off, which probably accounts for the frequently observable bursts of speed near it; the "lane" leading to it being merely an accustomed route, more or less forced by habit and obstructions on the bottom.

Abbott and early writers assumed that the female was the nest guardian, an idea dispelled by Gill (1889) and adequately discussed by him (1907). These earlier papers are not referred to here, as being unimportant in the light of later corrections and at best of interest only in a historical sense. See Dean (1916) for many such references.

TABLE IV.

Nesting dates of *Eupomotis gibbosus* in the vicinity of New York City.

Locality	Year	Pre-nesting Period	Nesting Period	Post-nesting Period	Temp. °C.
Branch Brook Park, Newark, N. J.	1913	—	June 13	—	—
	1926	—	June 6	—	20
	1927	May 11	—	—	—
Elmdale, N. J.	1926	—	May 28[1]	—	—
Haskell, N. J.	1928	—	July 15-17[2]	—	—
Hackettstown, N. J.	1933	—	July 23	—	—
	1934	June 25	—	—	—
Llewellyn Lake, N. J.	1934	May 20	July 14-29	Aug. 12	25.5
Sprain Lake, N. Y.	1934	—	—	Aug. 4	29
Pines Lake, N. J.	1934	June 15	July 6	Aug. 10	29
Lake Mohawk, N. J.	1934	May 20	July 14-29	Aug. 12	25.5
Kensico Reservoir	1935	June 9	June 14	Aug. 15	27.5
Byram Lake	1935	May 25	May 28	July 6	21
Pines Lake	1935	May 30	June 9-Aug. 14	—	22.5
Range of dates	.....	May 11-June 25	May 28-July 29	July 6-Aug. 12	20-29

[1] Eggs hatched June 1.
[2] Young fish 48 to 53 mm. standard length on Aug. 1.

Eupomotis microlophus (Günther).

There appears to be no specific data on this species, but presumably it would be found to be closely similar to its congener, if not identical.

Enneacanthus gloriosus (Holbrook).

The blue-spotted sunfish seems to have been peculiarly neglected by aquarists, although it is undoubtedly an attractive aquarium fish. Sawyer (1920) gives the only specific account we were able to locate of this species in aquaria but apparently he knew nothing of its reproduction. Bade (1932), in his general book, states that this species builds nests in aquaria. Incidentally, the several other species he describes are in good agreement with those given herein and are not referred to in each case. Fowler (1923) describes the nest as a "miniature sunfish nest in the moss with a diameter of four or five inches. In the bottom were rootlets to which the eggs adhere." Breder and Redmond (1929), working on the development of the eggs, were unable to find any nests, using stripped eggs for this purpose. This irregularity is similar to that of *Mesogonistius* and we now know that they may nest in the conventional sunfish manner or in plants, as is more fully discussed under that species. Nests usually in beds of filamentous algae are to be found in the New Jersey pine barrens, according to W. C. Bennett of the New York Aquarium (May 12, 1935). These nests are usually among lily pads and are not excavated all the way through the algae. Usually

the nests are nearly a foot in diameter, which larger size probably has to do with the softness of the material. The water depth is usually about one foot. See also under *Mesogonistius*.

Although the immature fish are conspicuously barred, the breeding females are more drab, as figured by Breder and Redmond (1929). The males are relatively brilliant but the pattern differs only slightly. They wrote: "There must be considerable rivalry among the males as is evidenced by the somewhat ragged condition of their fins, principally the caudal, during the mating season. In other local sunfishes much time is spent in nest building and while there is considerable rivalry it seldom seems to come to actual combat."

Enneacanthus obesus (Girard).

The species *Enneacanthus obesus* (Girard) may be distinct but at this writing there is certainly no reason to introduce this problem into a consideration of reproductive habits. As indicated by Breder and Redmond (1929) the fishes known to the author are *E. gloriosus*. Presumably the habits of these two, if they are eventually established as separate, should be closely similar.

Mesogonistius chaetodon (Baird).

The black-banded sunfish, confined to the strongly acid waters of the pine barrens of southern New Jersey and straggling southward in similar environments to Maryland, appearing again in the Carolinas, will apparently not thrive in waters of different and less acid content. The waters of their New Jersey habitat average in their acidity from about 4.0 to 5.0 pH. In aquaria with a range of about 6.5 pH upward we have not found them to thrive satisfactorily for any great length of time, which is not the case with the generality of centrarchids, or indeed with specimens of *Enneacanthus* taken in company with them from the same bog waters. The latter, however, have a much larger range and seem to accommodate easily a wide pH range.

Because of the attractive markings of the black-banded sunfish, aquarists have spent considerable effort in attempts to establish them in aquaria. Little success has been met in this direction and although some attempts at reproduction have been recorded we have yet to hear of a second generation of aquarium fish.

It was reported that this species built its nest in plants in an aquarium, Price (1915). He wrote that he observed "the male in the bunch of plants, about six inches from the bottom, busily engaged in making a hollow, somewhat like a bird's nest." Merget (1918), repeated by Werner (1930), describes a similar condition but mentions a previously made hole in the gravel below. Holbein (1926) and Wright (1928) both report nests in aquariums in the sand at the bottom, similar to other sunfish. The German aquarists, generally so successful in such matters, seem to be unable to add anything to this, Walk (1921), Henzelmann (1930) and Anonymous (1933). Abbott (1883) could not decide if nests were regularly constructed or not; at least he could not find anything of which he was sure.

These apparently contradictory statements are readily understandable in the light of field observations made by Mr. W. C. Bennett of the New York Aquarium staff, who is familiar with the haunts of these fishes and has collected them for a long time. In May, in the territory occupied by this species, many small dish-shaped depressions may be found in sandy spots in a foot of water or less. Some of these are occupied by *Mesogonistius* and some by *Enneacanthus*. Close examination divulges similarly sized depressions in beds of filamentous algae also occupied by both species and less frequently coarser plants will be pushed apart and such a sunfish found in the space so created. It is thus apparent that there is considerable varia-

tion in the selection of nesting sites. These nests average about four inches in diameter and are usually in about one foot of water. The Aquarium records, then, would seem simply to represent the spread of variation in habit to be expected.

There is little differentiation of the sexes, but Price (1915) reported that the male "became more transparent and pale, while the female grew more intense in color." On the basis that most female sunfish intensify their bands while the males tend to lose them at the time of breeding, this is perhaps to be expected. Males of other species generally have bright metallic spots that intensify, but since this species has no such basic features it is not surprising that they merely look pale on losing their usually strong vertical bars. Regarding courtship and spawning, Price (1915) wrote that when the nest was completed to the satisfaction of the male, "he darted swiftly toward the female. Before her he quivered and spread his fins, then swam back to the nest, repeating the performance several times. At last the female yielded to his pleading and followed him into the nest. Both trembled and vibrated, the pair in such a position that I was reminded of the movements of the wings of a butterfly." This latter statement describes well the typical centrarchid spawning position. The eggs hatched in two days (June 16 to 18). On the following day (June 19) they spawned again and the eggs hatched on June 21. There were two subsequent spawnings from this pair but the dates are not given. Merget (1918) mentions that the male guards the nest, which, of course is to be expected.

Archoplites interruptus (Girard).

There appears to be absolutely no data available on the reproductive habits of this species.

Ambloplites rupestris (Rafinesque).

The actual details of spawning of this species in captivity are given on previous pages as an illustration of the reproductive behavior of the Centrarchidae. See also Pls. III and IV, Figs. 3-6, and Table V for data on reproduction at the New York Aquarium. According to Evermann and Clark (1920), this species spawns earlier than other centrarchids in the region of their report, some nesting as early as May 15. The following bottoms have been noted for nesting sites: soil, Wright and Allen (1913); gravel, Bean (1903), Jordan and Evermann (1903), Tracy (1910), Hay (1894), Smith (1907); swampy places, Bensley (1915); marl, Hankinson (1908). In the tanks of the New York Aquarium this species has spawned in a depth of four feet, but this was the only depth available to them. The depth of water may range from a few inches, Bensley (1915), to about a foot, Hankinson (1908). Evermann and Clark (1920) say that the nest is usually placed beside a rock, stick or similar object. The diameter of the nests in aquaria was about two feet but the fishes were very large, old specimens. In the cases. observed the male guarded the nest and young and was successful until the young fish became too adventurous. The behavior of the rock bass in a state of nature has been described by Bensley (1915) and is quoted in the preceding general section.

TABLE V.

Data on the breeding of *Ambloplites rupestris* in the New York Aquarium[1].

Date	Hatch	Temperature °C	Time of Day
July 11, 1933	July 15	21.0-20.5	Before 9.00 A.M.
July 15, 1933	July 19?	20.5-20.5	After 3.00 P.M.
July 17, 1933	July 20?	20.5-20.5	?

[1] The female may have been the same, or different, each time.

Ambloplites cavifrons Cope.

If this species is valid it can be expected to perform in the manner described for the more widely distributed *A. rupestris*.

Acantharchus pomotis (Baird).

The nest of the mud sunfish has been recorded by Fowler (1923), who writes that it "has been observed nesting near Willow Grove Lake, in holes in a cranberry bog not far from Newfield, N. J., by R. O. Van Duesen. At this time, June 1st, the nest was guarded by the male. It was about a foot in diameter and resembled somewhat the nest of the long-eared sunfish. The depth of the water was about a foot, the bottom sand, mud around the periphery, and surrounded by spatter-docks. In location the nest was near the shore and partly shaded by trees." Breder and Redmond (1929) searched for the nests of this species in northern New Jersey but were unable to find nests or ripe adults, although numerous specimens were handled. Very young specimens were found in schools in the New Jersey pine barrens near Lakehurst about the middle of June by Mr. W. C. Bennett of the New York Aquarium staff. He noted that near these specimens a larger fish was hovering. Although he is extremely familiar with the region he never found a nest of the species. Apparently, for some reason not yet evident, this sunfish which is much more secretive than other members of the family is likewise more secretive with its nests.

Abbott (1884) considered this species to be nocturnal in habit, which would certainly account for some of the preceding remarks. He also stated that it "has a well developed voice" and that it produces "a deep grunting sound that cannot be mistaken." On capture many fishes may produce such a sound by grating their pharyngeals together or by vibrating their air bladder. If such sounds have any significance in centrarchid reproduction we have no evidence to that effect and the group should no doubt be considered voiceless as Gill (1907) suggested for *Eupomotis*. If *Acantharchus* is truly nocturnal it is possible that the voice noted by Abbott may have a real significance in this little-studied species, which would mark it as a distinct departure from the other and diurnal members.

Centrarchus macropterus (Lacépède).

Apparently no data has been published on the reproductive habits of this species in a state of nature. A short account of its courtship and spawning in aquaria is given by Heinrich (1921). His remarks, so far as they pertain to the present study, indicate agreement with the generality of sunfishes.

Pomoxis annularis Rafinesque.

Due to its frequent confusion with *Pomoxis sparoides*, the exact habits of this species, the white crappie, are uncertain but it is likely that they are closely similar to those of that fish. Forbes and Richardson (1909) say it apparently spawns in May in Illinois. Anonymous (1919) describes spawning presumably of this species, in the Aquarium of the U. S. Bureau of Fisheries, as occurring during the night of May 25, 1926. "The eggs were attached to a dense growth of algae covering stones in the obliquely inclined back of the tank and some of them were practically at the surface. The male fish jealously guarded the eggs and kept the water about them in constant motion with his pectoral fins. Other fish were kept away and objects that came near the eggs were savagely bitten. If a person placed his hand within six inches of the surface of the water, the male fish would leap clear of the water and strike the hand viciously."

Pomoxis sparoides (Lacépède).

Spawning of the black crappie or calico bass occurs in spring from early May, Richardson (1913), in Illinois, to early July, Evermann and Clark (1920), in Indiana, and in May in South Dakota, Churchill and Over (1933). Circular nests are constructed in shallow water of from ten inches, Richardson (1913), to two feet, Pearse (1919). The diameter may be about eight or nine inches, according to Evermann and Clark (1920). Spawning occurs when the water reaches about 68°F., Pearse (1919), but Richardson gives about 64°. The bottom selected varies considerably but apparently tends to be one of sand or fine gravel. A nest is described by Richardson (1913) as follows:

"It was hollowed out under the leaves of a water-parsnip, and surrounded by smartweed and bog rush (*Juncus*). Some of the eggs were adhering to fine roots in the bottom of the nest, but most of them were on the leaves of the water-parsnip, at a level of two to four inches above the bottom of the nest. The nest was guarded by a male, six inches long, who was so gentle that we could reach out a hand to within three feet of him before he moved away." Evermann and Clark (1920) state that the nests are usually at least five or six feet apart on fine gravel, coarse sand, with a few empty snail shells at times and are generally surrounded by *Chara*.

Pearse (1919) describes and figures the nest of this species along clay banks, here reproduced as Text-fig. 6. Pearse examined the stomach contents of nine males on nests and found them well filled with mostly aquatic insects. Many fish cease or nearly cease feeding during the spawning season but the sunfishes so far as known to the author all feed readily all during the reproductive period both in captivity and in a state of nature. Indeed, in most states, game laws designed to protect the black basses, *Micropterus* and *Aplites*, give a closed season during the breeding period to prevent anglers from catching these fishes from off their nests.

Text-figure 6.

The nest of *Pomoxis sparoides* under a clay bank. (After Pearse, 1919).

Elassoma zonatum Jordan.

The reproductive habits of the pigmy sunfish are described in aquaria by Poyser (1919). In his studies spawning took place at 71° and 72° F. Unfortunately he did not see the actual nest construction about which he wrote: "While I did not see the operation, the rubbish was cleared and heaped about the periphery, but not with the nicety of *Eupomotis gibbosus*, as much flocculent matter was allowed to remain." Of another male he wrote: "One of the sites was amid a dense growth of algae and nothing could be observed other than that the male was constantly there; certainly there was no attempt to form a nest. This instance leads me to believe

that under certain unfavorable bottom conditions no attempt may be made to clear a space if indeed this is not the normal method."

Courtship was described as follows: "This stage reached, the male at various times was observed making obvious efforts to attract a female, indulging in most amusing gyrations for such a 'stiff' and usually sedate fish. During these plays the body assumed the most intense coloring. . . . The dorsal was flabby but erect, waving with movement while the action of the caudal was quickened. A particular and conspicuous feature of the play was the rapid, rhythmic, alternate backward and forward 'clicking' of the ventrals, a feature I have not noticed in any other mating fish." This latter item is indulged in, as a matter of note, by other centrarchids, *Eupomotis*, *Lepomis*, *Aplites*, *Ambloplites* and probably to some extent by all, as well as in the Cichlidae, where it is notably conspicuous under various conditions as indicated by Breder (1934).

The spawning operation is described as a violent trembling after the "female approached quite unostentiously and without the slightest hesitation." Unfortunately no mention is made as to whether the female reclined on one side or not. This spawning took place immediately over the nest but another took place eleven inches above it at the surface. Another male intruded into this mating and both attempted to guard the subsequent eggs for a time. The spawnings occured at 9:30 A.M. and 8 A.M. respectively. The eggs are described as non-adhesive, but this seems unlikely, since a figure of an early egg shows some "peculiar process" which he was "unable to explain" and which would seem to be some exudate.

Barney and Anson (1920), studying the ecology of this species, found them spawning at 65° F., which is a week earlier than *Allotis humilis* in the same locality, as the former breed in shallower water which warms to the same temperature that much earlier. The habits so far as described are in good agreement with those observed in aquaria.

Elassoma evergladei Jordan.

Three aquarium descriptions of the spawning of this species, Rachow (1926), Mayer (1929) and Anonymous (1931), all agree in considering this species a non-nest builder. The eggs are described as attached to plants and other objects.

The descriptions of courtship are closely similar to those of the preceding species and the male is described as being decidedly black. Spawning occurred many times at intervals of about two weeks, with relatively few eggs laid at a time.

DISCUSSION.

The data presented in the preceding pages clearly show the Centrarchidae to be extremely uniform in their methods of reproduction. This is in harmony with their restriction to the more quiet fresh waters of a single continent. Confined, as they are, to a single basic type of habitat it is perhaps not surprising that a reproductive method not uncommon to such localities is used by all of them. Other fishes using methods more or less similar, in similar localities, include such diverse forms as many of the Siluridae, the Cichlidae, *Amia* and *Heterotis*. While it is true that various species associated with the Centrarchidae spawn in diverse manners, it is also true that such fishes all agree in spawning at an earlier time, when the water is cooler; *e.g. Perca, Morone, Stizostedion, Esox, Umbra, Notemigonus, Fundulus, Pomolobus*, etc. Presumably the temperature thresholds on which the various fishes spawn is largely a matter of physiological differences. Consequently those forms that spawn late, on a higher temperature, are forced to provide for the greater oxygen demand that the temperature itself induces. Thus, while silting is of little importance

to slow-breathing eggs of *Esox* and *Perca* in much colder water, the same amount of silting on sunfish eggs might well be suffocating. Also, at this later season, the temperature-controlled invertebrate predators are more active. As has already been indicated, sunfish eggs hatch well without parental attention in clear water protected from enemies. The function of the parental activity would thus seem clearly associated with the temperature at the time of spawning and the effects incident to it.

If an attempt is made to trace the possible phylogeny of nesting habits in the Centrarchidae, there is little to work on. The closest relatives, the Kuhliidae, are in part marine, living mostly in open water, and according to Meek (1916) "appear to spawn inshore, in brackish or fresh water." Some species live in fresh water in rivers, but not enough is known of their reproductive habits to be useful in this connection. Since such centrarchid eggs as have been tested are demersal in even excessively dense sea water, it matters little whether we consider for present purposes the centrarchid or the kuhliid method as primitive, since neither gives any associative inferences. Perhaps both modes lead back to a common ancestral one, as both families are generally considered as evolved from some central percoid type. In all the great aggregation of Percoidei there seems to be no form of reproduction that could be used as a likely starting point of centrarchid habits. The Cichlidae, Nandidae, Etheostomidae, Labridae and the Pomacentridae all seem somewhat to resemble the centrarchids in reproductive habit but certainly they are each removed too far to be little more than chance resemblances. All of the rest show no parental care, or it is so different in nature as surely to be an entirely independent development.

The serranid, *Roccus lineatus* (Bloch), lays slightly heavy non-adhesive eggs while those of *Morone americana* (Gmelin) are heavy and very adhesive. Both species are anadromous where the latter is not landlocked; both spawn earlier than the centrarchids and there is no parental care. It is conceivable that some such habit might lead to nesting and guarding by a physiological need for a higher temperature to induce gonadal stimulation. The two forms, mentioned as non-nesters, resort to special places that are suitable for the eggs to develop in, which of course is the first step to nest construction. All this is little more than speculation and it will not be pushed further, as the inferences are obvious.

Considered from the standpoint of what this habit might lead to, one is confronted with the strong probability that the centrarchids are terminal along their line of reproductive specialization. Since it has been shown that various nest building groups that use their mouths to a considerable extent in nest construction or in manipulating eggs have members which practice the curious habit of oral incubation, it might be expected that the centrarchids would give rise to such a habit. Three diverse groups—Cichlidae, Siluridae and Labyrinthidae—all show such behavior, Breder (1933, 1934a and b, 1935a) and there are at least two other groups falling within the same category on which there is too little data for profitable speculation. One is the Osteoglossidae and the other the Apogonidae, a member of the Percoidei. We cannot, however, attempt to associate the apogonids with the centrarchids, as the former are all marine and show evidences of being a secondary invasion of reef environments from deep water, which is reflected in their bright red coloration and large eyes. So far as known they all practice oral incubation.

With these remarks on the present inability to derive centrarchid habits from others, or others from them, this part of the discussion may be left with the comment that our present knowledge of the exceedingly uniform reproductive behavior of this family completely fails to tie it in with those of any of its possible relatives.

Examining the slight differences within the family Centrarchidae there

are some inferences discernible which are at least fairly suggestive. The genera *Micropterus* and *Aplites* which Hubbs (in litt.) suggests recognizing as a subfamily, Micropterinae, spawn earlier than the other genera associated with them. Since these fishes have departed less from the central percoid type than the rest, it may be that this slightly earlier spawning is an indication of a still earlier one in the ancestral forms, without the construction of a nest. Nest construction, nevertheless, is as well developed in this group as in the rest.

Those Lepominae for which Hubbs (in litt.) suggests the tribe Lepomini, including *Chaenobryttus, Apomotis, Sclerotis, Lepomis, Helioperca, Xenotis, Lethogrammus* and *Eupomotis*, so far as their habits are known, are quite similar in regard to reproduction. Such differences as are sometimes seemingly apparent would seem to refer to mechanical circumstances of fish and environment, as is indicated in the specific considerations. It is in this group that extensive natural hybridization has been found, a condition in itself giving some measure of reproductive similarities. These fish all follow the Micropterinae in time of spawning, in the same waters.

The dwarf lepominid sunfishes, tribe *Enneacanthini*, according to Hubbs' suggestions including only *Enneacanthus* and *Mesogonistius*, are relatively late spawners, overlapping the time of Lepomini. The frequent failure of these fish to construct a fully formed nest is apparently a tendency to a secondary loss of the habit. It would be difficult to think of them as only now developing the habit from a non-nesting ancestor, since it is so typical of other sunfish nests when made.

The tribe Ambloplitini, including *Archoplites, Ambloplites* and *Acantharcus*, of which the nests of only the second two are known, is again typical. They spawn relatively early as compared with the other Lepominae, apparently deriving their reproductive habits from some form similar to the Micropterinae with little change.

The subfamily Centrarchinae, including *Centrarchus* and *Pomoxis*, is too scantily known in regard to reproductive habit to warrant much speculation, but apparently differences are slight. Spawning in *Pomoxis* is relatively early and would seem to be sometimes in deeper water than in other forms.

The pigmy sunfishes, generally considered a separate family, the Elassomidae, would seem to be a subtropical specialization. The single genus, *Elassoma*, diminutive as it is, shows the typical sunfish reproductive habits. In aquaria, at least, it may sometimes forego nest building in a manner analogous to that of the dwarfish Enneacanthini.

The temperature differences as here discussed are indicated in Table VI. So far as these figures are reliable they show the primitive Micropterini as earliest, with the Centrarchinae, Elassomidae and Ambloplitini next. The Lepomini have the highest mean value but a much greater spread than either the Enneacanthini or Elassomidae.

TABLE VI.

Comparison of the nesting temperatures of the centrarchids.

Group	Temperature °C.		
	Minimum	Maximum	Mean
Centrarchidae			
Micropterinae	15.5	21	18.25
Lepominae			
Lepomini	20	29	24.5
Enneacanthini	21	23	22
Ambloplitini	20.5	21	20.75
Centrarchinae	18	20	19
Elassomidae	18.5	22	20.25

Sex recognition, mating, parental care and other factors are so similar or imperfectly known as to render no clues to the phylogeny of habit. For the present, then, it is necessary to leave the habits of this group without any very evident connections with others. They stand alone, as a compact assemblage, with a highly specialized reproductive habitus in which the traces of heritage are not evident.

The general tendency for immature fish, females and frightened males, to show a series of dark vertical bars may be tentatively explained as representing the basic color pattern that is overridden in the males by the effect of the sex harmones. Just what significance, if any, this may have is certainly not clear at this time. Known behavior gives no clue to this.

There is a marked tendency for the males of the Centrarchidae to grow to a larger size than the females, as has been indicated by the following: *Eupomotis gibbosus*, Creaser (1926); *Micropterus dolomieu*, Tester (1932); *Eupomotis gibbosus* and *Helioperca macrochira*, Hubbs and Hubbs (1932); *Xenotis megalotis*, *Apomotis cyanellus* and *Ambloplites rupestris*, Hubbs and Cooper (1935). The latter suggest that this inversion of the usual size difference between the sexes in fish may have to do with the active protecting role that the males assume.

Considered in a broad way the annual cycle of habit in the Centrarchidae presents an interesting series of items of behavior largely controlled by temperature.

Starting in the winter the fishes are found in a semihibernating state. They may be aggregated in compact masses or variously scattered about individually. *Micropterus dolomieu*, Townsend (1916); *Lepomis auritus*, *Acantharchus pomotis*, *Pomoxis sparoides*, Breder and Nigrelli (1934), all have been noted to form aggregations on temperature reduction. *Eupomotis gibbosus*, *Chaenobryttus gulosus*, *Ambloplites rupestris* and *Enneacanthus gloriosus* were noted by the latter authors not to aggregate under similar conditions. The factors involved in causing aggregation in the species studied are numerous and not entirely clear. Whether the differences noted are genetic or purely environmental in the various species is not fully evident at this time and there is nothing we can add to the remarks of Breder and Nigrelli (1934) and Langlois (1936). At least in no species is fighting known below a certain temperature. Consequently as the fishes naturally seek optimum locations they are more or less drawn together on a purely mechanical basis, without considering any social impulses. This also tends to segregate the smaller, last season's, fishes from the older, since on a size basis alone their needs are somewhat different.

As the temperature rises in the spring feeding is the first evident reaction. In this connection it may be mentioned that sunfishes feed continuously until the cold weather of fall drives them into hibernation again. This is somewhat unusual among fishes, since feeding is frequently interrupted by breeding activities in many forms.

Shortly after feeding has well commenced, concomitantly with the developing gonads in the males, shallow water is sought out for nesting purposes. That this is not purely a temperature factor encouraged by a seeking of the warmer shallow marginal water is evident from the fact that the males precede the females by an irregular but frequently not inconsiderable time. It would seem that the increasing temperature and longer hours of daylight (?) have a more immediate effect on the males than on the females. Daylight is specifically mentioned in this connection partly because of the demonstrated role it plays in other vertebrates, including fishes, Breder and Coates (1935b), and because of the obvious importance sunlight plays in the reproductive habits of sunfish, as already discussed. The males begin their nest construction even in the absence of females, this activity being stimulated by internal gonadal influences. At this time the males become hostile toward one another and tend to scatter. Limitations of suitable bottom somewhat counter this, causing colonies of nests frequently to be formed.

TABLE VII.

Comparison of the reproductive habits of the Centrarchidae with those of the silurid *Ameiurus nebulosus* and the cichlid *Aequidens latifrons*.[1]

	Ameiurus nebulosus	*Centrarchidae*	*Aequidens latifrons*
		Differential behavior	
1. Sex recognition	Tactile or chemical?		
2. Spawning position	Pair head in opposite directions in close contact.	Pair headed the same way with their ventral surfaces in contact, the female reclined on one side.	Pair usually with male following female, but never in contact.
3. Location of nest	In a cavity.	In a depression in sand or gravel made by the male.	*Not* in a cavity; on a hard surface.
4. Nature of eggs	Slightly adhesive, adhere in a mass.	Moderately adhesive, attached to gravel and each other.	Strongly adhesive, no eggs in contact.
5. Need of aeration	Necessary for respiration of the eggs.	Not essential for respiration of the eggs. A protection from silting and enemies only.	Not essential for respiration of the eggs. A protection from enemies only.
6. Roles of parents	Female does most of the incubating, while male guards (sometimes both incubate).	Male alone incubates and guards. Female normally leaves when eggs are laid.	Male does most of the incubating, while the female guards (sometimes both incubate).
7. Incubating method	Chiefly the ventral fins by means of a vertical motion aided by the anal.	Chiefly the pectoral fins aided by the anal, or swimming motions of the whole body.	
8. Eggs taken into mouth	For churning, to insure adequate aeration (and cleaning?).	For the return of the young to the nest (?).	For removal of hatching young to the "nursery" and for returning them only.
9. Care of young	Kept in or close to nest, but for which there is no special construction.	Guarded in nest by male until ready to swim. Sometimes guarded until later.	Remove to a shallow hole especially prepared.

[1] Data on *Ameiurus* from Breder (1935a) and on *Aequidens* from Breder (1934a).

The still more or less aggregated females begin to cruise about, eventually entering the nests and spawning. Their attention to family life is only momentary and their aggregation usually does not fully or permanently disintegrate. The courtship activities of the male, which seem to be indistinguishable from the fighting attitude, may be exhibited to other fish or inert objects. The reaction of other males is generally one of flight, rarely fighting, while that of females is one of attraction, the resulting behavior thus being dependent on the activity of the visiting fish. Parental care generally extends only to the time of hatching but there is some control of the fry, especially in the Micropterinae, which is much like that of the cichlids.

In the absence of suitable bottom nests may be constructed in which reproduction is impossible, including sites with too rapidly flowing water or mud that is too soft and flocculent. On a really hard bottom, such as a cement floor, no nest is formed but the motions are made and the spawning may be successful. The mechanics of nest making seem to be more or less constant, the substratum determining the features of the nest. The influences determining the selection of a given spot seem to include chiefly the existence of a prior depression, the proximity to a protecting object, such as a rock, and the distance from the nearest other male. The same general areas are used year after year in most cases, suggesting a certain amount of habit formation. This would not be surprising when it is considered how common such a habit is in other fishes, becoming spectacular only in forms undertaking long migrations. The movement inshore from deep water can hardly be considered a migration in the ordinary sense of the word but it is undoubtedly of the same nature.

After the reproductive period has passed, aggregating is again sometimes evident, but solitary feeding is the principal business and aggregations if appearing at all do not show up strongly until the winter approaches. This statement also applies to the young of the year after they leave the nest.

A comparison of the features of the reproductive habits of two unrelated species with the sunfishes is given in Table VII. The data on the silurid, *Ameiurus nebulosus* (Le Sueur), is modified from Breder (1935a) and that on the cichlid, *Aequidens latifrons* (Steindachner), Breder (1934a). Three of the nine items listed in the table—1, 5 and 7—may serve to describe broadly both the centrarchids and the cichlid, whereas none serves mutually for the silurid and either of the others.

This may be interpreted in one of two ways. Since the centrarchids and cichlids are both Percoidei it may be that the genetic relationship, remote as it is, is expressing itself in these general resemblances. On the other hand it may be that these are really parallelisms. In this connection it may be recalled that the cichlids more or less replace the centrarchids in Central and South America, or vice versa, considered in a general ecological sense. The much more distantly related silurids also adopting nesting habits have all the details differently arranged. Whether these differences can be considered as of genetic difference of heritage or whether they are of mechanical circumstance is not easily settled. The silurids are basically olfactory types, whereas the percoids here considered are distinctly visual types. How much of the difference can be associated with the predominance of one receptor or another and its resulting influence on effectors can only be speculated upon at present.

SUMMARY.

1. The reproductive habits of the Centrarchidae are remarkably uniform.

2. In all known, the male constructs the nest and guards the eggs, the female being only concerned with their deposition. In a few, nest construction may sometimes be omitted.

3. Sex recognition is apparently based entirely on the differential behavior, from all other fish, of females ready to spawn.

4. The position and form of the nest are controlled by a large number of purely physical factors in the environment and include: temperature, sunshine, depth of water, rate of flow, nature of bottom, proximity of protecting objects, etc.

5. The position of the nest in regard to other nests is controlled by a centrifugal effect between the males and a centripetal effect induced by limitations of suitable bottom and probably as well by some form of population hierarchy.

6. Already-existant nests of other species are frequently made use of.

7. In all species studied the spawning positions are closely similar, the male remaining in an upright position and the female reclining to one side.

8. Success in defense of the nest is apparently based more on the fact of the owner being on familiar territory, rather than on any intrinsic fighting ability.

9. Well made nests are marked in the Micropterinae, Lepomini and Centrarchinae and least in the Enneacanthini, Ambloplitini and Elassomidae.

10. The extent of parental care follows the above, being most prominent in the primitive Micropterinae.

11. The development of the centrarchid type of reproduction is not clear phylogenetically, due in part to the relatively isolated position of the group and to the lack of information on the nearest relatives.

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EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Part of a typical colony of *Eupomotis gibbosus* nests on rough bottom at Pines Lake, New Jersey. All but one nest was occupied at the moment of exposure and a female is approaching the nest in the upper left-hand corner.

PLATE II.

Fig. 2. A male *Eupomotis gibbosus* on its nest at night in the colony illustrated in Fig. 1. Photographed by flashlight.

PLATE III.

Fig. 3. *Ambloplites rupestris* nesting on a concrete aquarium floor. The stones are embedded in the cement. The positions are typical of those immediately before spawning. The approaching female is at the right.

Fig. 4. The spawning position of *Ambloplites rupestris*, showing the female reclined on her side. This photograph was taken shortly after that of Fig. 3.

PLATE IV.

Fig. 5. A guarding male *Ambloplites rupestris* in a typical warning attitude. Some of the eggs may be detected adherent to the stones under the head of the fish. Photographed the day following that of Pl. III, Figs. 3 and 4.

Fig. 6. *Ambloplites rupestris* with their nest constructed in fine sand in a small aquarium. The upper fish is the female.

PLATE V.

Fig. 7. *Eupomotis gibbosus* fanning out its nest. This is, perhaps, the most typical position and posture of the nest building activity. This and the following four photographs are of the same fish.

Fig. 8. *Eupomotis gibbosus* in its typical "yawning" posture while guarding the nest.

PLATE VI.

Fig. 9. *Eupomotis gibbosus* with a typical nest built in sand in an aquarium. Note that a few empty snail shells have been left in place. To these the eggs were attached.

Fig. 10. *Eupomotis gibbosus* picking over the smooth sand of its nest.

PLATE VII.

Fig. 11. *Eupomotis gibbosus* during the spawning act. Note the prominent bars on the female, which is in front of the male.

Fig. 12. A typical solitary nest of *Eupomotis gibbosus* in fine sand. Note the position in relation to the rocks as compared with those of the colony shown in Pl. I, Fig. 1, Pines Lake, New Jersey.

PLATE I.

FIG. 1.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.

PLATE I.
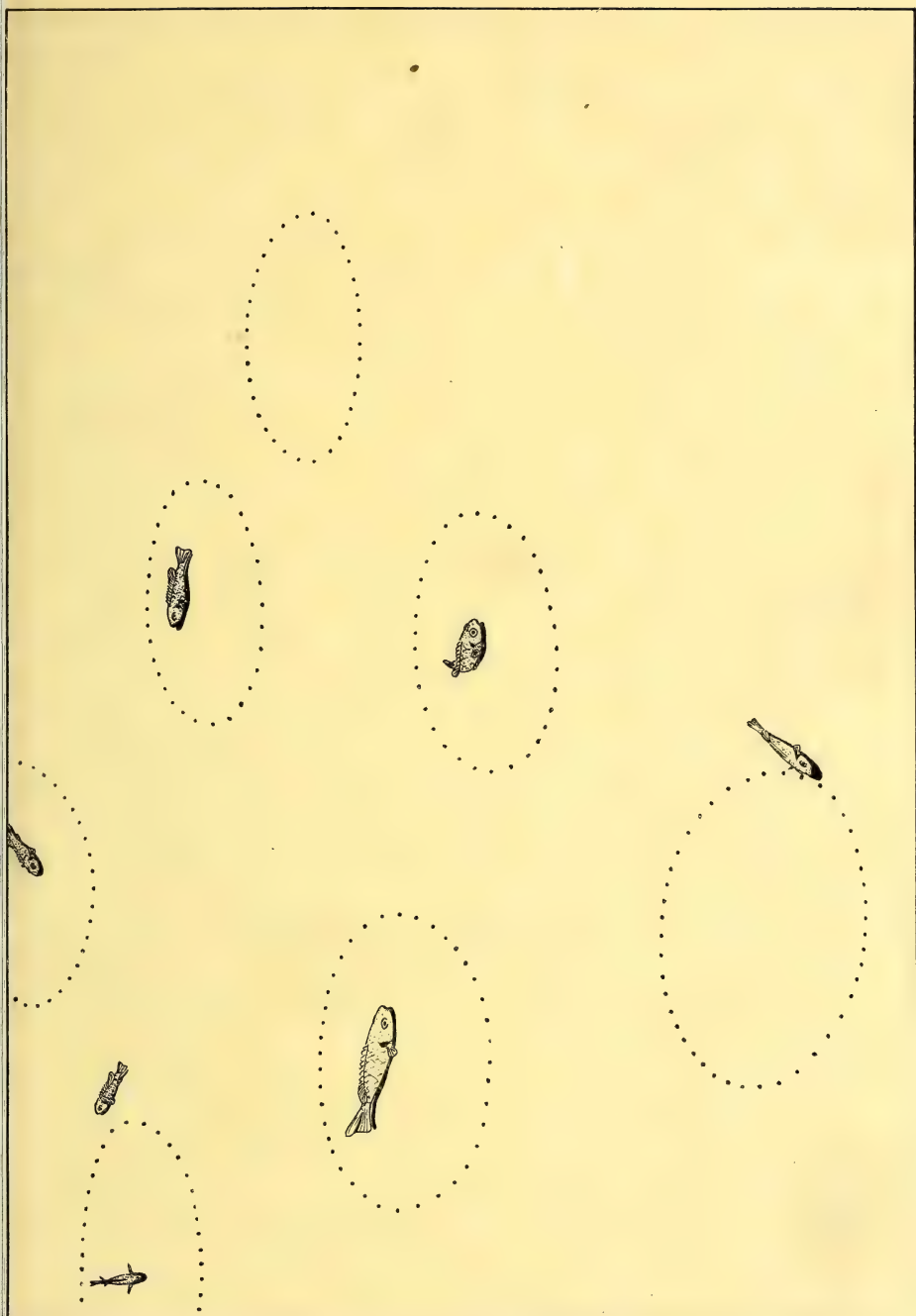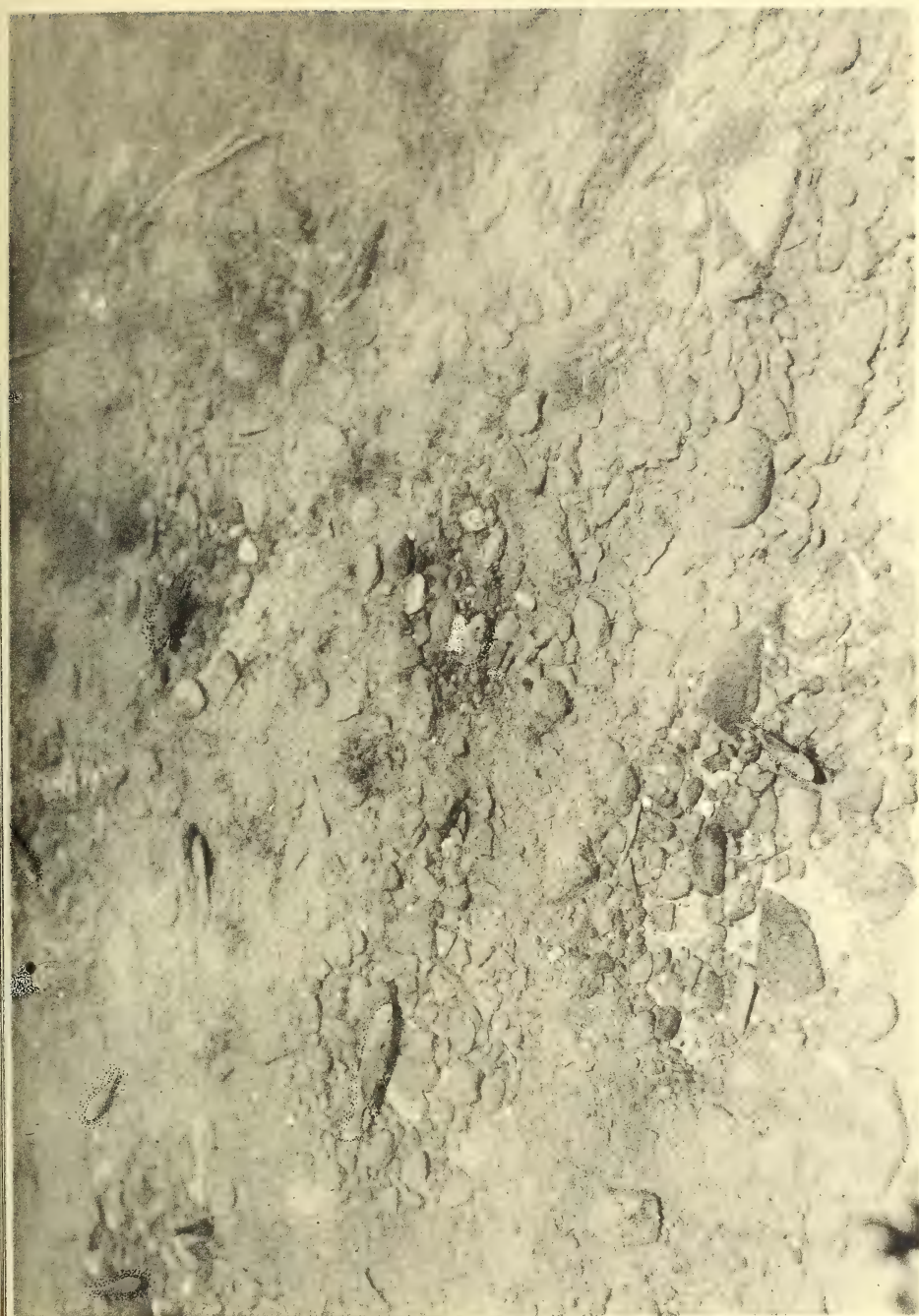
FIG. 1.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.
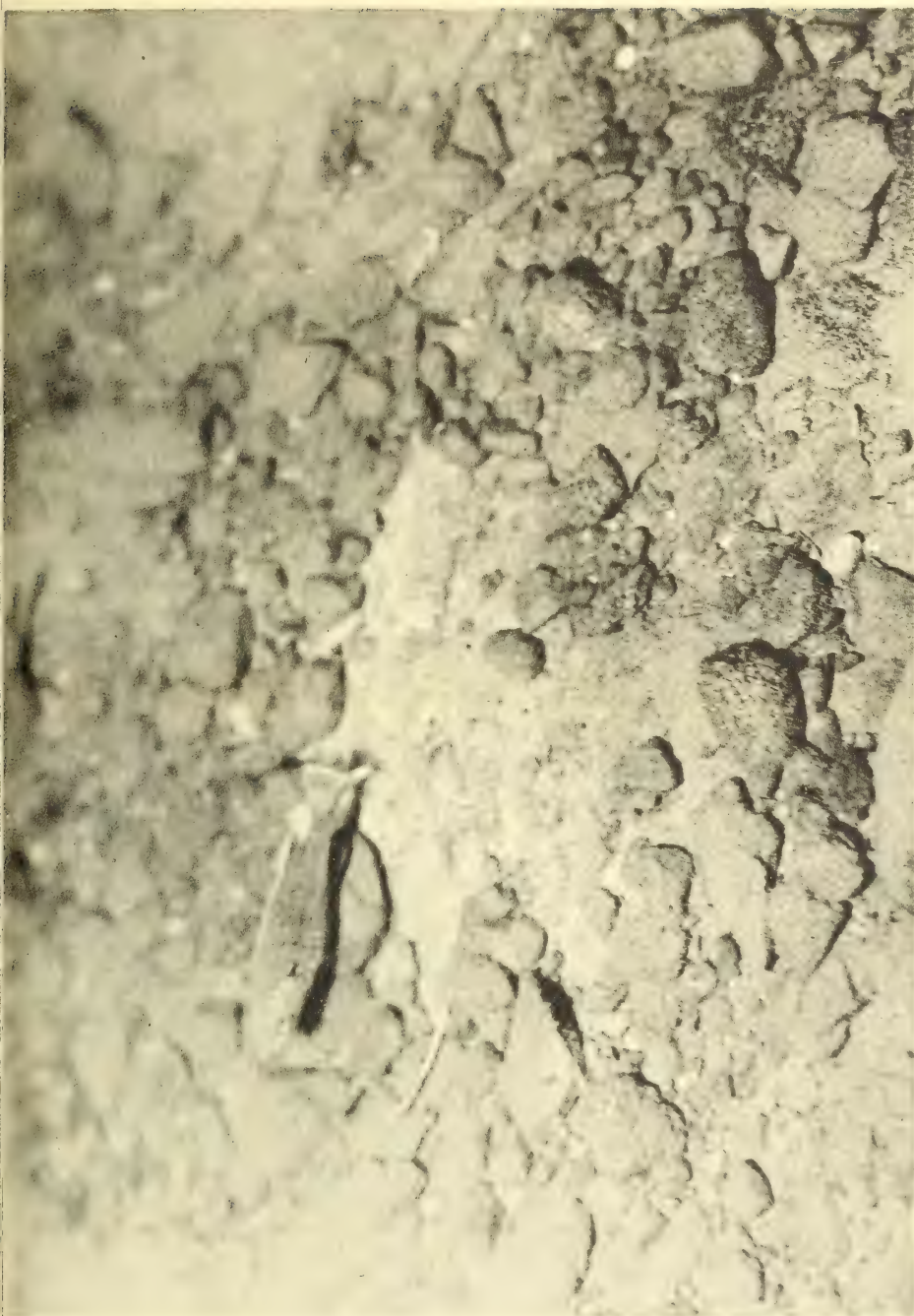
FIG. 2.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.

PLATE III.
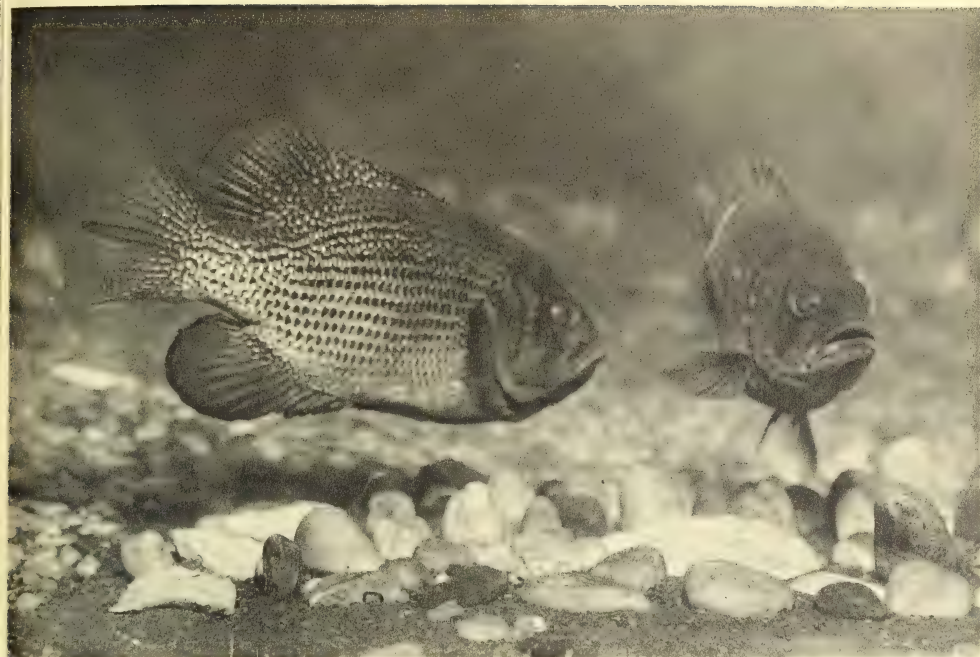
FIG. 3.

FIG. 4.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.

FIG. 5.

FIG. 6.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
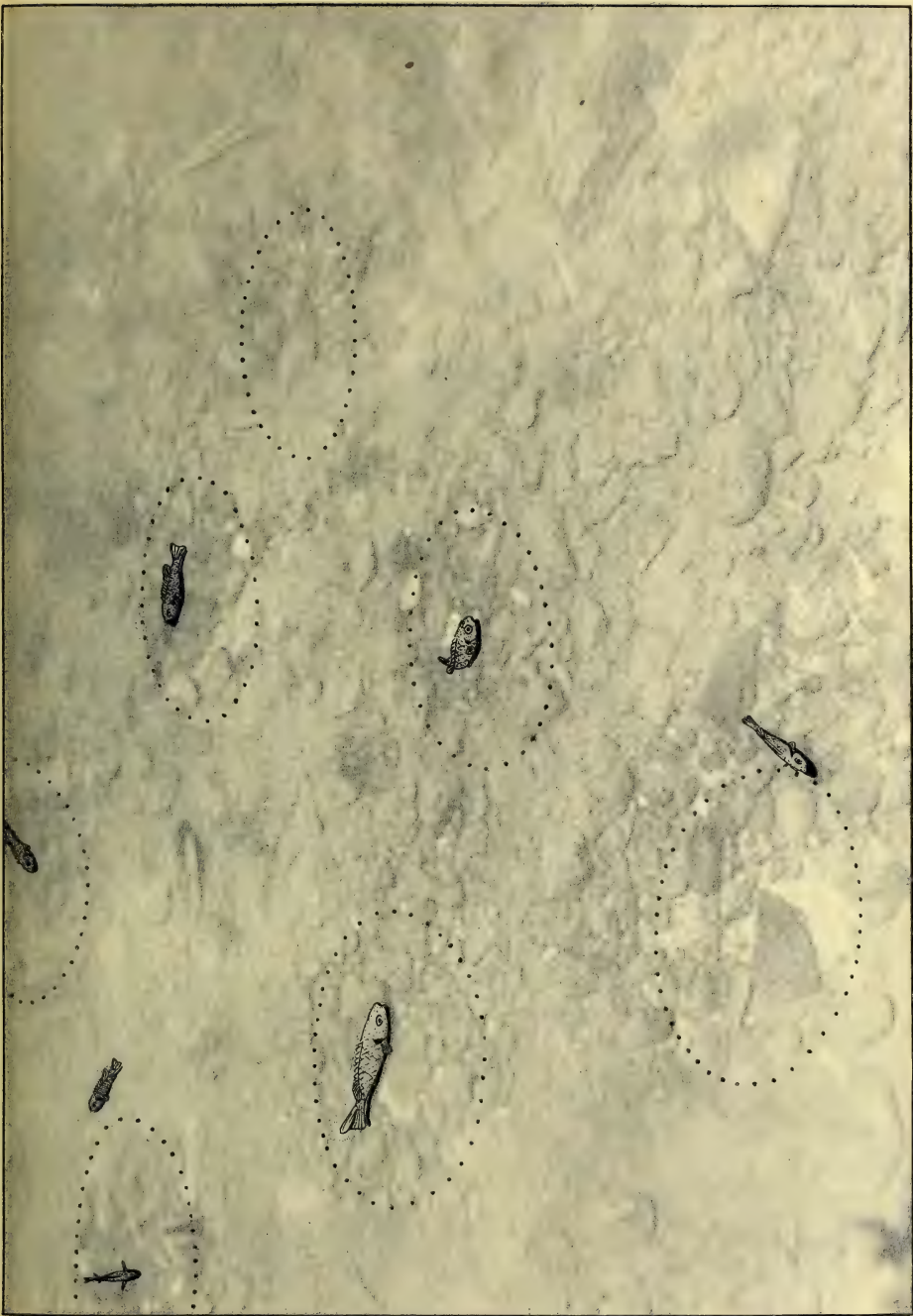SUNFISHES, FAMILY CENTRARCHIDAE.

PLATE V.

FIG. 7.

FIG. 8.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.
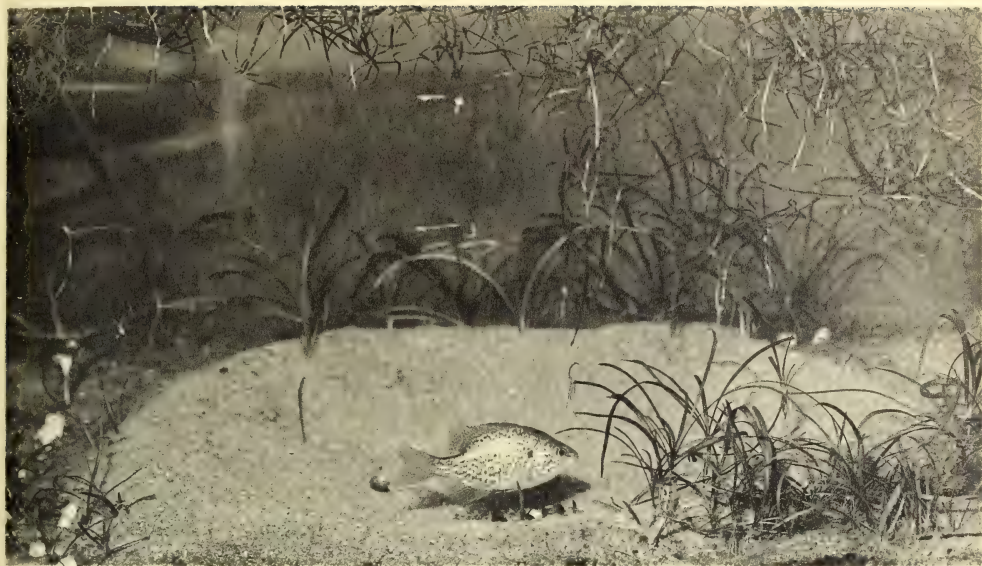
FIG. 9.

FIG. 10.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.

FIG. 11.

FIG. 12.

THE REPRODUCTIVE HABITS OF THE NORTH AMERICAN
SUNFISHES, FAMILY CENTRARCHIDAE.

2.

Polychaetous Annelids from the Vicinity of Nonsuch Island, Bermuda[1]. By A. L. Treadwell, Vassar College.

(Plates I-III)

Introduction.

The following is a taxonomic account of some polychaetous annelids collected in the vicinity of Nonsuch Island, Bermuda, in the years 1929-1931, in connection with the work of the Department of Tropical Research of the New York Zoological Society and submitted to me for study by Dr. William Beebe. The greater number of individuals are pelagic species collected during the deep-sea operations but a few are from shallow water and shore localities, some of the latter collected by the writer while a guest at the laboratory in August, 1931. For data relating to the Bermuda locality and to the nets in which the pelagic species were taken, see Zoologica, Vol. XIII, Nos. 1, 2 and 3.

A list of families represented and of new and old species occuring in the collection follows:

Family	Old species	New species
Syllidae	1	..
Amphinomidae	2	..
Polynoidae	2	2
Sigalionidae	..	1
Chrysopetalidae	1	..
Glyceridae	?	?
Aricidae	1	..
Nereidae	3	..
Leodicidae	10	..
Tomopteridae	..	1
Alciopidae	1	..
Phyllodocidae	3	..
Opheliidae	2	..
Typhloscolecidae	..	1
Cirratulidae	..	2
Sabellidae	1	1
	27	8

Two papers dealing solely with the polychaetous annelids of Bermuda have appeared, those of Webster (1884) and Verrill (1900). Webster's was a report on collections made by G. Brown Goode, while Verrill did extensive collecting and study on the islands. Some annelids are described from Bermuda localities in McIntosh's (1885) Report on the annelids of the *Challenger* Expedition and in a paper by Hoagland (1919). Bermuda was grouped with the West Indian region in a monograph by the present writer

(Treadwell, 1921) and while the main object of that paper was a study of the Leodicidae, collections made in Bermuda in 1916 demonstrated that in its essential features the annelid fauna of Bermuda is of the West Indian type. This is noticeably the case in the Leodicidae, with the exception that the Atlantic "palolo," *Leodice fucata* Ehlers, which is very abundant farther south, has never been seen in Bermuda. A considerable number of species listed by Ehlers (1887) occur in Bermuda and this monograph should be available to any one studying the annelids of that locality.

Systematic Account.

Family Syllidae.
Typosyllis Langerhans.
Typosyllis corallicola Verrill.

Typosyllis corallicola Verrill, 1900, p. 603.

One specimen collected in tidepool, Nonsuch Island, Aug. 16, 1931 (No. 311,355).

Trypanosyllis Claparède.
Tetraglene phase.

With large numbers of *Polyophthalmus* (see p. 61, Nos. 311, 487 and 311-, 436), there were collected under electric light at the Nonsuch Island boat landing a few individuals that I have identified as the tetraglene phase of an unknown species of *Trypanosyllis*. They average a length of 5 mm. and a width of not more than 0.5 mm. The body is flattened and its most characteristic features are the relatively enormous brown eyes and the brown pigment patches on both dorsal and ventral surfaces near the bases of the parapodia. There are no tentacular cirri or antennae. All cirri are jointed, almost moniliform in character, the dorsal ones longer than the body width, the ventral ones hardly longer than to the ends of the parapodia. The anal cirri are from one-third to one-half as long as the body and very large, each at its base being wider than half the width of the pygidium. Notopodial setae are numerous, slender capillary in form and are longer than the transverse diameter of the body. Neuropodial setae are compound, the terminal joint varying in size, some being hardly longer than their own basal width, others four times as long as this. Behind the apical tooth is a small subapical one.

Family Amphinomidae.
Hermodice Kinberg.
Hermodice carunculata Kinberg.

Hermodice carunculata Kinberg, 1857, p. 14.

Collected in Castle Harbor, April 30, 1930 (No. 30,672) and Nonsuch Island.

Eurythoe Kinberg.
Eurythoe pacifica Kinberg.

Eurythoe pacifica Kinberg, 1857, p. 14.

Collected in tidepool and coral rock, Oct. 22, 1930 (No. 301,360); Sept. 12, 1930 (No. 301,675).

Family Polynoidae.
Polynoe Savigny.
Polynoe granulata Ehlers.

Polynoe granulata Ehlers, 1887, pp. 50-51; Pl. 11, Figs. 2-7.
Collected in coral, Gurnet's Rock, Bermuda, 35 feet deep, Sept. 29, 1930 (No. 301,308) ; and from reef in Castle Harbor, Aug. 14, 1931 (No. 311,298).

Harmothoe Kinberg.
Harmothoe fragment sp. ?

Collected in Net 928, 500 fathoms, Sept. 20, 1930 (No. 301,128).

Eunoe Malmgren.
Eunoe purpurea n. sp.
(Figs. 1—6).

The body of the type specimen is 18 mm. long, its greatest width 5 mm. and it has 28 somites. The coloration varies somewhat in the different specimens, the characteristic color and the one on which the specific name is based being a purplish brown which is most pronounced on the anterior face of the prostomium, the bases of the palps and the base of the proboscis. In none is the proboscis more than very slightly protruded and it is not clear how much of it shows this coloration. In one specimen, not much colored elsewhere, the ventral surface, except for the mid-line, is dusted with this pigment. In others the anterior and posterior thirds of the dorsal surface are similarly dusted but in all cases the median dorsal third of the body surface is uncolored. In one, the mid-ventral longitudinal line has a pearly lustre and in another this is uncolored but there is on either side a grayish green narrow band.

The width of the prostomium is roughly twice that of its length and all angles are rounded (Fig. 1). The large heavily pigmented eyes occupy the outer four corners of the prostomium, their colorless lenses being projected downward so as not to be visible from the dorsal surface. The peak on either side is extended into a slender cirrus-like process and the anterior margin is deeply incised for the insertion of the cirrophore of the median tentacle, which is short and globular and has the appearance of a goblet supported on a slender stalk. The style of the median tentacle is lost from all specimens. The cirrophores of the lateral tentacles lie ventral to the peaks. Their length is about equal to their width and they extend to about the same distance as the median one. Their styles are short and inconspicuous. The palps are very long and heavy, fully eight times as long as the prostomium. At their bases they are often pigmented, this pigment showing a tendency to arrange itself in fine transverse lines. No dorsal cirri remain and the tentacular cirri are too much mutilated for an accurate description, but they are evidently much longer than the lateral tentacles. The ventral cirri on the first two or three parapodia are very large, extending beyond the seta tips, but in later parapodia they become progressively smaller. In Fig. 1 the one shown at the left is a broken tentacular cirrus and the one on the right is the first ventral cirrus.

The parapodia (Fig. 2, of the 16th), have a large neuropodium and a very small notopodium, each having a large acicula which extends through and beyond the tip of the lobe. In this parapodium (the 16th), the ventral cirrus extends considerably beyond the neuropodial tip. In the notopodium there are a very few heavy setae (Fig. 3), with some much smaller. In the

parapodium figured the numbers were 2 and 3 respectively. The neuropodial setae are of two kinds. The dorsalmost are the more slender and nearly straight and carry two rows of sharp spines (Fig. 4). The ventralmost ones vary in size, the smallest being near the ventral margin and in proportion as they increase in size they acquire a deeper yellowish color. All broaden toward the ends and then taper to a slender and slightly curved apex. Along their broadened regions they carry transverse rows of toothed plates. The heavy dorsal setae also have transverse plates but these are very short and their margins only faintly toothed. (Fig. 5). Note the difference in the scales of magnification between Figs. 3 and 5.

Of the entire collection, only one elytron remains, the 1st or 2nd. It is circular in outline and its surface is densely studded with sharp spines (Fig. 6). These are larger near the middle of the elytron than around the margins.

The type was collected in Net 838, 600 fathoms, Sept. 3, 1930 (No. 30,694), and is in the collections of the Department of Tropical Research of the New York Zoological Society. Other specimens were taken in the following nets: Net 847, 500 fathoms, Sept. 4, 1930; Net 868, 900 fathoms, Sept. 10, 1930, (No. 30,838); Net 902, 700 fathoms, Sept. 17, 1930 (No. 301,018); Net 942, 1,000 fathoms, Sept. 24, 1930 (No. 301,193); Net 1,000, 700 fathoms, June 5, 1931 (No. 31,126); and Net 1,004, 600 fathoms, June 6, 1931 (No. 31,155).

<div align="center">

Drieschia Michaelsen.
Drieschia atlantica n.sp.
(Figs. 7-9).

</div>

There are three specimens in the collection, all more or less mutilated. The type which is broken near the centre but evidently retains all of its somites, is 12 mm. long and its greatest diameter, just back of the head, is 1 mm. The prostomium (Fig. 7) has rounded posterior angles and its lateral margins are only slightly incurved to meet the cirrophores of the lateral tentacles. These latter are not sharply separated from the prostomium and are about one-quarter as long as it. There is no marked anterior incision for the attachment of the cirrophore of the median tentacle, which in the type is not sharply separated from the lateral ones. In other specimens the distinction is sharper. The median cirrophore is about twice as thick as the lateral and a trifle longer. The eyes are small but prominent, the anterior pair lying near the lateral margins at about the middle of the prostomium while the posterior pair are near the posterior margin and are closer together than the anterior.

The style of the lateral tentacle is about twice as long as the cirrophore, slender and sharp pointed, and that of the median tentacle is more than four times as long as the lateral and very slender in relation to its length. The palps are also slender. In the type they extend to a distance considerably beyond the tentacle tip but in another specimen (probably injured), they are much shorter. The tentacular cirri are also slender and as long as the palps.

The parapodia are uniramous, the notopodium being absent (Fig. 8). The neuropodium is cylindrical and sharp pointed, having a single acicula and a small ventral cirrus not reaching the apex of the parapodium. In all cases the cirrophore of the dorsal cirrus is inflated to form a hollow structure which in some anterior somites may be larger than the parapodium and completely obscure it from a dorsal view. The cirrophores are largest in the 5th and 7th parapodia and decrease in size posteriorly, though their size relative to the parapodium is not so much less in this region. Too many of the styles have been lost to determine the point with

accuracy but it seems as if, posterior to the 7th parapodium, the styles are alternately long and short. They are all very slender. There are 2 slender anal cirri.

Just dorsal to the apex of the parapodium is a tuft of two or three long and slender setae and ventral to it a few much larger ones. These latter (Fig. 9) broaden slightly toward the end and then narrow to a blunt point, this terminal portion being very slightly spoon-shaped and carrying a series of small toothed plates along the concave surface.

The type has 14 pairs of elytrophores but all of its elytra are lost. One other specimen retains the most anterior and most posterior one on one side. Apparently in life they cover the entire dorsal surface of the body. Descriptions of elytra from other species of this genus speak of them as "inflated," this together with the inflated character of the dorsal cirrophores being correlated with their pelagic mode of life. Neither of the two above mentioned elytra showed any sign of inflation but they very probably were so when alive, for they look very much as a very thin-walled disk-shaped sac might look if it were collapsed and its wall thrown into wrinkles. The outline is nearly circular, the margin smooth and the surface covered with numerous wrinkles running in all directions.

The type was taken in Net 953, 1,000 fathoms, Sept. 26, 1930 (No. 301,259) and is in the collections of the Department of Tropical Research of the New York Zoological Society. The others were taken in Net 841, 500 fathoms, Sept. 4, 1930 (No. 30,719) and Net 939, 1,000 fathoms, Sept. 24, 1930 (No. 301,176).

<div align="center">

Family Sigalionidae.

Eupholoë McIntosh.

Eupholoë nuda n. sp.

(Figs. 10-14).

</div>

A single specimen 30 mm. long and 3 mm. wide. The prostomium (Fig. 10) is hemispherical in outline but is truncated on its anterior margin for the insertion of the single tentacle. The tentacle is small, its apex not reaching to the ends of the underlying setae. There is a pair of small eyes on the dorsal peristomial surface and a much larger pair on the ventral, not visible from the dorsum. There are no tentacular cirri on the specimen. In Fig. 10 the prostomium is drawn as if the anterior dorsal margin of the 3d somite, which when in place completely covers it, were drawn back. The cirri figured at the sides are the dorsal cirri of the 3d somite. The first two parapodia with their setae crowd together under the prostomium and are in contact on the ventral line, lying between the prostomium and the palps. The 2d parapodia extend forward of the prostomium and as stated above, the 3d somite extends over the prostomium. The palps are slender and extend only to a short distance beyond the ends of the first setae. The first ventral cirrus is large, the next one smaller and throughout most of the body they are very small.

In this genus the elytra should form an overlapping series along both margins of the body, leaving the greater part of the surface uncovered. In *E. nuda* no elytra are present, although oval or round areas looking like the scars left when elytra are torn off occur in the appropriate somites. The most reasonable conclusion would be that elytra were lost, but careful examination of these structures fails to reveal any trace of torn or ragged edges such as should appear if this had been the case. The dorsal body surface is sprinkled with fine sand grains which extend down to the parapodia and show no trace of disturbance in the places where elytra should have been. It seems certain that the specimen is normally lacking in elytra. These sand grains are quite uniformly scattered over the dorsal

surface, being generally a trifle larger in the mid-line than elsewhere but otherwise show no differences in different body regions. The ventral surface is thickly studded with short rounded papillae (Fig. 11) which give it a "shagreen" appearance. On the dorsal surface of each parapodium, and lying just under the above mentioned elytral "scar" is a single "branchia" in the form of a blunt papilla whose length only slightly exceeds its breadth.

The parapodia (Fig. 11) have large neuro- and very much smaller notopodia, the former truncated at the apex, giving it a triangular outline. The notopodium is much smaller, looking like a mere outgrowth from the neuropodium. It carries on its upper surface a small knob-like protuberance. Each lobe has a single acicula. The ventral cirrus is small and does not reach the end of the neuropodium. On the ventral and lateral surface of the parapodia are numerous papillae.

The notopodial setae form a dense bunch radiating from a common center on the dorsal face of the notopodium. They are slender and sharp pointed and each carries two rows of toothed plates (Fig. 12). Two kinds of setae occur in the neuropodium. The more dorsally placed ones are very large and heavy, the terminal joint relatively rather short, and are without any subterminal tooth (Fig. 13). Ventral to these is a tuft of more slender setae in which the terminal joint is relatively longer and more slender and has a single very slender subterminal tooth (Fig. 14). The relative sizes of these two kinds of setae are shown in Figures 13 and 14, which are drawn to the same scale.

The genus *Eupholoë* was established by McIntosh (1885, p. 157), for *E. philippinensis,* on a single specimen dredged off Mindanao in the Philippines (1885, pp. 157-159, Pl. 22, Figs. 6, 7; Pl. 24, Fig. 7; Pl. 25, Fig. 10; Pl. 13A, Figs. 16, 17). The diagnosis is as follows: "Body elongated, somewhat truncated in front and tapering posteriorly, the former end being covered with coarse and the latter with fine, sand grains. Elytra small, confined to the lateral regions and furnished with peculiar processes which like the other parts of the scales are covered with long cilia. A rudimentary branchia (?) on each foot. Dorsal bristles slender with long spinous rows, ventral with single short terminal processes beneath the hook of which is a minute spine." In the detailed description and figures of *E. philippinensis* the prostomium has exactly the structure of *E. nuda,* but tentacular cirri are absent from the latter (presumably by accident) and the two first parapodia do not crowd together under the prostomium in *E. philippinensis* as they do in *E. nuda.* A minor difference is that in *E. nuda* the sand grains on the dorsal body surface are of uniform size throughout. Whether the elytra in the latter species are really absent must be determined when other material is available for study. McIntosh's Fig. 16, Pl. 13A, is exactly like Fig. 12, while his Fig. 17 is essentially like Fig. 13 except that he represents a very small subterminal tooth. In his drawing this looks more like an accidental irregularity than a tooth, and it may be that the two are alike in structure. He does not figure the more slender ones like Fig. 14.

The type is in the collections of the Department of Tropical Research of the New York Zoological Society and was collected in coral at Gurnet's Rock, Bermuda, 35 feet deep, Sept. 29, 1930 (No. 301,308).

Family Chrysopetalidae.
Bhawania Schmarda.
Bhawania goodei Webster.

Bhawania goodei Webster, 1884, pp. 308, 309; Pl. 7, Figs. 10-15.

Collected from reef in Castle Harbor, Aug. 16, 1931 (No. 311,350) and from coral at Gurnet's Rock, 35 feet deep, Aug. 19, 1931 (No. 311,483).

Family Glyceridae.
Glycera Savigny.

Two very young specimens of this genus, too immature for identification, collected in Net 824, 800 fathoms, Sept. 1, 1930 (No. 30,672).

Family Aricidae.
Nainereis Blainville.
Nainereis setosa Verrill.

Aricia setosa Verrill, 1900, pp. 651-653.
Two specimens, collected on mud flat, St. David's Island, Bermuda, Aug. 17, 1931 (No. 311,397).

Family Nereidae.
Nereis Linnaeus.
Nereis bairdii Webster.

Nereis bairdii Webster, 1884, pp. 312-313; Pl. 8, Figs. 22-28.
Collected at Gurnet's Rock, 35 feet deep, Aug. 19, 1931 (No. 311,481); tidepools, Nonsuch Island, Aug. 16, 1931 (No. 311,357); and mud flats, St. David's Island, Aug. 17, 1931 (No. 311,396). These were all in crevices in coral rocks from shallow water.

Heteronereis phase.
(Figs. 15, 16).

Specimens collected in Net 817, 600 fathoms, Aug. 29, 1930 (No. 30,630); and Net 834, 400 fathoms, Sept. 3, 1930 (No. 30,680) were identified as *N. bairdii* from their jaw structure (Webster's Figs. 22a and 23). The prostomium carries very large eyes, those of the same side in contact with one another and their lenses small. The peristomium is swollen so as to be as wide as the 1st somite (compare Webster's Fig. 22 for the atokous phase). In one of the two specimens there are 14, in the other 18, somites in the anterior region. This anterior region is widest at about the 6th somite and from here narrows in either direction. The tentacles and palps are little changed from the atokous condition but appear larger because of the swollen prostomium. Neither specimen is entire, one retaining some thirty somites in the posterior region, the other fewer. The tentacular cirri retain the relative length of the atokous phase but their bases are heavier and in the preserved material have a general "ram's horn" effect. In the anterior region dark brown pigment patches lie on the body wall just dorsal to the parapodia, the usual arrangement being one nearer the anterior and one nearer the posterior border of the somite. These patches are much darker in one specimen than in the other.

The anterior parapodia are not noticeably different from those of the atokous phase except that the dorsal cirrus acquires a broader base and becomes lanceolate in outline. The setae show no change (see Webster's Figs. 26 and 27). The structure of the parapodia of the modified region can best be understood by reference to Fig. 15, taken from the smaller of the two specimens. Neither of the two contains sex products and from the smooth character of the dorsal cirrus I assumed that this is a female. The other specimen, however, is larger and in this, while the character of the general modification is the same, the dorsal cirrus shows the lobings characteristic of the male. It seems certain therefore that both are males but that one has not yet fully reached the epitokous condition. The setae

are numerous, extend considerably beyond the parapodium lobes and have the characteristic broad terminal joints.

Nereis glandulata Hoagland.

Nereis glandulata Hoagland, 1919, p. 575; Pl. 30, Figs. 1-6.

Heteronereis phase. (Fig. 17). Identified by a comparison of the jaws with Hoagland's Figs. 2 and 3. This species also has very rounded parapodial lobes and a pigment patch on the parapodium (Hoagland's Fig. 4), which characters are retained in the anterior somites of the epitokous phase. The prostomium, except for increase in the size of the eyes, is not much changed from the atokous condition. The 1st somite is about equal to the prostomium in width and from there there is a gradual increase in width to the 6th somite. In this anterior region the only change is in the character of the dorsal cirrus, which is larger in all somites and in the middle of the region has the avicular character shown in Fig. 16. The setae are unmodified (compare Hoagland's Figs. 5 and 6). In the posterior, modified region the parapodia are as in Fig. 17. Since the dorsal cirrus is lobulated I have assumed that both are males. The setae are numerous, long and have the usual heteronereid form.

Collected in Net 767, 800 fathoms, July 3, 1930 (No. 30,382); and Net 775, 1,000 fathoms, July 4, 1930 (No. 30,396).

Nereis mirabilis Kinberg.

Nereis mirabilis Kinberg, 1865, p. 170.

Nereis gracilis Webster, 1884, pp. 313, 314; Pl. 9, Figs. 29-35.

Name preoccupied. See Kinberg *loc. cit.*, p. 170.

Collected at Gurnet's Rock, Bermuda, in coral, 35 feet deep, Sept. 29, 1930 (No. 301,308); Castle Harbor, reef, Aug. 15, 1931 (No. 311,334); and tidepools, Nonsuch Island, Aug. 16, 1931 (No. 311,357). Found in association with *N. bairdii* in decomposing coral rock.

A number of small heteronereids collected Aug. 18, 1931, swimming at the surface under a light, are evidently *N. mirabilis*, because they show the very unusual character of the prostomium of this species which is little changed in the heteronereid. The first dorsal cirri are somewhat expanded but the others show no modifications. The parapodia of the modified region have the usual fin-like lobes.

Family Leodicidae.
Leodice Savigny.
Leodice mutilata Webster.

Eunice mutilata Webster, 1884, pp. 315-316; Pl. 9, Figs. 36-40.

Leodice mutilata Treadwell, 1921, pp. 30-33; Pl. 3, Figs. 5-8; Text-figs. 66-76.

In the collections sent me, this was recorded only from Gurnet's Rock, 35 feet deep, Sept. 29, 1930. It was abundant, however, in the collections I studied on Nonsuch Island, and is the commonest *Leodice* of the region, occurring in dead coral rock. From the twisted position it assumes among the rock crevices, it is difficult to extract without breaking, a peculiarity which probably accounted for Webster's specific name.

Leodice culebra Treadwell.

Leodice culebra Treadwell, 1921, pp. 49-51; Pl. 2, Figs. 13-16; Text-figs.
    144-153.
Collected in tidepools, Nonsuch Island, Aug. 16, 1931.

Leodice longicirrata Webster.

Eunice longicirrata Webster, 1884, pp. 318, 319; Pl. 12, Figs. 75-80.
Leodice longicirrata Treadwell, 1921, p. 11-15; Pl. 1, Figs. 1-4; Text-
    figs. 3-12.
Collected at Gurnet's Rock, 35 feet deep, Sept. 29, 1931 (No. 301,308)

Leodice denticulata Webster.

Eunice denticulata Webster, 1884, pp. 316-317; Pl. 10, Figs. 41-45.
Leodice denticulata Treadwell, 1921, pp. 22-25; Pl. 3, Figs. 1-4; Text-
    figs. 41-53.
Collected at Gurnet's Rock, 35 feet deep, Aug. 19, 1931 (No. 311,482).

Nicidion Kinberg.
Nicidion kinbergii Webster.

Nicidion kinbergii Webster, 1884, pp. 320, 321; Pl. 12, Figs. 81-88.
                     Treadwell, 1921, pp. 91-93; Pl. 6, Figs. 6-8; Text-
                     figs. 324-332.
One specimen, locality uncertain. It is generally found in the harder
portions of the dead coral rock near low water mark.

Marphysa Quatrefages.
Marphysa regalis Verrill.

Marphysa regalis Verrill, 1900, pp. 636, 637.
Marphysa fragilis Treadwell, 1911, pp. 2-5; Figs. 1-7.
Marphysa regalis Treadwell, 1921, pp. 66-69; pl. 5, Figs. 9-12; Text-
    figs. 224-234.
Collected at Gurnet's Rock, 35 feet deep, Sept 29, 1930 (No. 301,308);
tidepools, Nonsuch Island, Sept. 12, 1930 (No. 301,675). It is very common
in the soft beach rock.

Marphysa acicularum Webster.

Marphysa acicularum Webster, 1884, pp. 319-320; Pl. 10, Figs. 50-53.
                       Treadwell, 1921, pp. 57-59; Pl. 5, Figs. 1-4;
                       Text-figs. 184-193.
Collected on St. David's Island, Aug. 17, 1931 (No. 311,399). It is com-
mon in muddy flats between tide levels.

Paramarphysa Ehlers.
Paramarphysa obtusa Verrill.

Paramarphysa obtusa Verrill, 1900, pp. 646, 647.
                       Treadwell, 1921, pp. 76, 77; Text-figs. 269-278.
Collected in coral, Gurnet's Rock, 35 feet deep, Sept. 29, 1930 (No.
301,308).

Dorvillea Parfitt.

In most of the literature this genus is given as *Staurocephalus*. Verrill (1900, pp. 647, 648) gave reasons for changing it to *Stauronereis*. Chamberlin (1919, p. 339), applying the laws of priority, showed that it should be *Dorvillea*.

Dorvillea melanops Verrill.

Stauronereis melanops Verrill, 1900, pp. 647, 647.
                    Treadwell, 1921, pp. 125-127; Text-figs. 459-467.
A single small specimen was collected with numerous individuals of *Polyophthalmus* (see p. 61) under electric light at the boat landing on Nonsuch Island (No. 311,436) on the evening of Aug. 18, 1931. When adult, it is not a pelagic species.

Dorvillea erythrops Verrill.

Stauronereis erythrops Verrill, 1900, pp. 649, 650.
One specimen, taken under electric light, Nonsuch boat landing, Aug. 19, 1931 (No. 311,485).

Family Tomopteridae.
Tomopteris Eschscholtz.
Tomopteris longisetis n. sp.
(Figs. 18-21).

Noticeably different from previously described species in that the second cirrus with its seta is considerably longer than the body. The following measurements were taken from four of the best preserved specimens.

Total body length	Length of Second cirrus	No. of parapodia
55 mm.	65 mm.	38.
23 mm.	31 mm.	25.
22 mm.	27 mm.	?
55 mm.	90 mm.	38.

The parapodial number given refers only to the well defined body somites and does not include the rudimentary ones of the "tail." In the third of the above measurements the number was uncertain owing to imperfect preservation. As has before been recorded in this genus, the somite number varies with the total length.

In general body appearance *T. longisetis* differs from the usual in that the body is broader in proportion to its length and the separation between body and parapodia is much less distinct. The parapodia are short and thick and are in contact at their bases, giving the whole body a much more compact appearance than is usual. In other species the parapodia may be as long as the body width; in this they are shorter.

In preserved material the body is opaque and in some has a pearly white appearance, while others are brownish in tint. The tentacles (Fig. 18), are slender and extend to the 2nd parapodium. The 1st cirrus is absent. The 2d cirrus has a triangular base whose apex extends about as far as to the end of the tentacle. Seen from the ventral surface the cerebral ganglion with commissures and ventral cord are prominent features, being lighter in color and more opaque than the remainder of the body. Anterior to the cerebral ganglion and visible on the ventral surface is a pair of small eyes which look as if they are borne on narrow lobes

extending anteriorly from the cerebral ganglion. From the 1st to the 4th parapodium there is a regular increase in length, the 4th being about twice as long as the 1st. From the 4th backward there is a very slight increase in length as far as the anterior third of the body and behind this a gradual decrease to the narrow posterior end, the parapodia in all cases having a definite size relation to that of the somite to which they are attached. Their form is much the same throughout the body except for the "tail" where they are cylindrical structures with a mere hint of a bifid apex.

The parapodia (Fig. 19) have short thick bases and bifid ends, the end portions equal in size and each carry a much fluted fin extending all around the terminal margin. The glandular structures are confusing in this material. In the larger specimens where this fluting is most noticeable, no trace of glands could be seen. In the smaller specimens the ventral lobe of the parapodium carries a large gland-like structure, the row of these when seen under low magnification looking like a series of suckers (Fig. 20). These have no color. In the smallest specimens each apical branch of the parapodium has on its outer margin a rosette gland with a dark sepia color (Fig. 21). In some cases the rosette glands are not pigmented. In the unusual length of the second cirrus, *T. longisetis* agrees with *T. nisseni* Rosa, as described by Southern (1910, p. 17, Pl. 1, Figs. 1 and 2), but is fundamentally different in that *T. nisseni* has fewer parapodia.

Specimens were taken in 18 deep sea nets, drawn from 500 to 1,000 fathoms, during May 17-28, 1929, Sept. 1-24, 1930, and July 25 to Aug 18, 1931 (Nos. 29,475; 29,476; 3,050; 30,116; 30,537; 30,623; 30,757; 301,122; 301,124; 301,125; 301,129; 301,155; 301,675; 31,840; 311,078; 311,103; 311,164; 311,432).

Tomopteris sp?

A single specimen 35 mm. long, with tail 15 mm. in length, thus the tail relatively longer than in *T. longisetis*. The parapodia are much more distinct from the body than is the case in the latter species, are longer and more slender and are without marginal frill. There is a single very large opaque rosette gland on each ventral branch. On one side of the ventral region is what seems to be a 1st cirrus and eyes are present, but the whole is too much macerated for accurate description. The 2nd cirrus is not more than one-half as long as the body. Because of gradual modification of the parapodia until they seem to fade away into the general body surface, it is not easy to determine their number in the tail region but there are at least twenty. Taken in Net 792, 600 fathoms, July 9, 1930 (No. 30,486).

Family Alciopidae.
Vanadis Claparède.
Vanadis fusca-punctata Treadwell.

Vanadis fusca-punctata Treadwell, 1906, pp. 1159, 1160; Figs. 29-31.

The species was described from specimens collected in the Hawaiian Islands. Others were taken at the Galápagos Islands by the *Arcturus* Expedition (Treadwell 1928, p. 462) and it is the most abundant species in the Bermuda collections. It can easily be recognized by the form of the head region and the rows of dark spots on the body.

Collected in 52 deep sea nets from 0 to 1,000 fathoms during the following dates: May 20 to June 17, 1930; Aug. 28 to Sept. 25, 1930, and June 3 to Aug. 14, 1931. (Nos. 29,471; 3,069; 30,121; 30,229; 30,234; 30,531; 30,576; 30,591; 30,608; 30,637; 30,640b; 30,656; 30,660; 30,661; 30,788; 30,846; 30,875; 30,915; 301,101; 301,135; 301,180; 301,226; 3,183; 31,245; 31,312; 31,315; 31,338; 31,347; 31,365; 31,390; 31,391; 31,392; 31,436;

31,437; 31,438; 31,472; 31,496; 31,589; 31,594; 31,610; 31,630; 31,635; 31,661; 31,681; 31,706; 31,712; 31,756; 31,866; 31,927; 311,131; 311,184; 311,207; 311,254).

Fragments, probably of this species but too much injured for accurate identification, were collected in 11 other nets towed at depths from 25 to 1,000 fathoms during June, 1930, and June 15 to Aug. 11, 1931 (Nos. 30,142; 30,841; 30,987; 30,990; 301,199; 31,217; 31,456; 31,681; 31,749; 31,758; 311,174).

Family Phyllodocidae.
Phyllodoce Savigny.
Phyllodoce oculata Ehlers.

Phyllodoce oculata Ehlers, 1887, pp. 135-140; Pl. 40, Figs. 4-6.

Collected in coral, Gurnet's Rock, 35 feet deep, Sept. 29, 1930 (No. 301,308) and August 19, 1931 (No. 311,484) ; Castle Harbor, Aug. 15, 1931 (Nos. 311,333; 311,336).

Lopadorhynchus Grube
Lopadorhynchus nans Chamberlin.

Lopadorrhynchus nans Chamberlin, 1919, pp. 116-119; Pl. 17, Figs 1-5.

Two well marked varieties of this species are in the collection. Most are slender, not more than 10 mm. in length, pearly white in alcohol and must have been translucent when alive. The others are generally much longer and have thick, opaque, yellowish brown bodies. Both agree with Chamberlin's description of the form of the head and anterior somites. Chamberlin's single specimen was taken between Easter Island and Peru in 17° 55′ S. Lat. and 87° 42′ W. Long. The Bermuda specimens were taken in 10 deep-sea nets, ranging from 50 to 1,000 fathoms, during September, 1930, and from July 6 to Aug. 19, 1931. (Nos. 30,863; 301,138; 301,181; 31,453; 31,470; 31,494; 31,609; 31,633; 31,999; 311,476).

Lopadorhynchus uncinatus Fauvel.

Lopadorhynchus uncinatus Fauvel, 1916, pp. 57-61; Pl. 1, Figs. 2, 3; Pl. 4, Figs. 1-4.

Easily recognized by the excessive development of the first two parapodia. Fauvel in his diagnosis of the species says that the eyes are black, but in the later description he describes them as having a more or less circular margin of brown. In this respect and in the distribution of the chromatophores over the body surface the Bermuda specimens agree with Fauvel's, which were collected in the vicinity of Monaco. The Bermuda specimens were taken in the following nets: Net 945, 500 fathoms, Sept. 25, 1930 (No. 301,213), Net 947, 700 fathoms, Sept. 25, 1930 (No. 301,224) and Net 967, 500 fathoms, Sept. 30, 1930 (Nos. 301,314).

Family Opheliidae.
Ammotrypane Rathke.
Ammotrypane bermudiensis n. sp.
(Figs. 24-26).

The body is rounded dorso-laterally and flattened ventrally with a deep longitudinal groove along the ventral surface. Since intersegmental constrictions do not appear, the number of somites can only be estimated by the seta tufts of which there are 32 pairs, situated ventro-laterally. The type

is 32 mm. long, its greatest width 2.5 mm. From apex of prostomium to the first seta tuft is 1.5 mm. The anal tube is 3 mm. long. At the posterior end the somites (as indicated by the seta tufts), are very closely crowded together. The prostomium is conical (Fig. 24), its basal diameter being equal to one-half of its length and it carries a small mucron on the apex. From the base of the prostomium there is a slight increase in width to the middle of the body and from there a decrease posteriorly. At its base the anal tube has the same width as the last somite, but it narrows to an apex about one-half as wide. It is cylindrical in form with transverse markings in some cases clearly marked, in others more obscure. The anal opening is dorso-terminal and is bounded laterally by two thin plates whose free edges in some cases show simple scalloping, in others carry about six short papillae (Fig. 25). What seems to be the normal condition of the anal cirri is that there is one pair of short rounded ones, with a longer and more slender one between them, located on the anal tube near its ventral surface. They are sometimes covered over and obscured by the cirri of the last setigerous somites.

Cirrus-like gills occur in each setigerous somite except the 1st. They are long and slender and extend approximately to the mid-dorsal line. Laterally, pigment spots first appear posterior to the 5th seta tuft on either side and are continued posteriorly for at least 21 somites. The first two pairs are very small, the next nine pairs are much larger and the remaining pairs are small again. Associated with each of the two posterior pairs of these pigment spots is a much larger spot, located ventrally and more deeply imbedded in the body tissue so that it is seen only obscurely from the surface.

The pharynx is only partially protruded in any specimen but apparently is cylindrical. On either side of its base is a tuft of papillae which would locate this species in Kinberg's genus *Terpsicore* (1865, p. 257), but it lacks the anal cirri given by Kinberg as diagnostic of that species.

The parapodia (Fig. 26) are very small, the neuropodium having a prominent rounded end, and the seta tuft arises posterior to that. The notopodium has several rounded lobes and the dorsal seta tuft arises between its base and that of the gill. The gills are very large relative to the parapodium (Fig. 26). The ventral setae are much shorter than the dorsal and are fewer in number, all being unilimbate, curving gently to an acute apex. The dorsal setae are of varying lengths, some being nearly as long as the gill, others much shorter, but in general are much longer than the ventral ones. All are very narrowly limbate. The central axis is markedly striated.

The type was collected in sand near Nonsuch Island, 10 feet deep, June 25, 1929 (No. 29,470). Others were taken in sand, 35 feet deep, near Gurnet's Rock, April 6, 1929 (No. 29,473), and in sand near Nonsuch Island, 10 feet deep, Oct. 1, 1931 (No. 312,233). A considerable number are recorded simply as from Castle Harbor in sand in association with *Asymmetron*. There is a marked superficial resemblance between the annelid and the cephalochordate which has been commented upon by various writers.

Polyophthalmus Quatrefages.
Polyophthalmus incertus n. sp.
(Figs. 27-29).

In material collected under electric light at the wharf on Nonsuch Island on the evening of Aug. 18, 1931, was a single specimen of *Polyophthalmus* which is the type of this new species. On the following evening a large number of much smaller specimens of the same genus were collected at this locality. The type is 8 mm. long and while the ones collected later may reach a length of 5 mm., they are so slender that they give the impression of being very much smaller. When alive in sea water their form

and movements give them very much the appearance of nematodes. The type is well preserved but for some reason the preservation methods which have given excellent results in other cases did not succeed with the others, the cuticle being much swollen and thrown into folds so that the animals look as if they are living in a definite "haus." The rarity of the genus makes it important that its occurrence should be recorded though the present scarcity of material prevents a thorough species diagnosis. Furthermore, since the species is not generally pelagic, it is probable that these are immature stages. The following description must therefore be regarded as tentative, to be corrected and expanded when better material is available.

The type is marked by 14 lateral "eye spots" of which the 1st is very small, the 2nd about twice as large as the 1st and the 3rd more than twice the size of the 2nd. The 4th to 9th inclusive are of the same size as the 3d, while the next 5 become successively smaller. In the anterior part of the body pigment patches occur in a scattered arrangement over the dorsal surface but in about the region of the 1st lateral eye spot these are more definitely localized in the mid-dorsal line and throughout the greater part of the body they occur as transverse brown patches in the mid-dorsal surface, presumably arranged somitically, though the somite limits are not easy to determine. At the posterior end the body narrows into a tubular pygidial region (Fig. 29) which carries a row of about twenty cirri around its posterior margin. This pygidial region is marked on either side by a series of 7 pigmented rings.

The prostomium (Fig. 27) is broadly rounded and carries one pair of prominent brown eyes. Behind the eyes is a transverse suture, presumably indicating a nuchal organ. The mouth (Fig. 28) is an elongated slit, having fleshy lateral lips.

Throughout most of the body the setae are very small and few in number so that they are difficult to see, but at the posterior end, where the body is beginning to narrow into the pygidial region, 4 somites carry each a dorsal and a ventral tuft of very long setae, longer than the transverse diameter of the body at this point. The setae are very slender and sharp pointed.

In its body pigmentation this species apparently resembles *P. pictus* Dujardin, but differs decidedly from that in the form of the head and tail regions as figured by Fauvel (1914, pp. 247, 248, Pl. 22, Figs. 8, 9).

The type was collected at an undersea lamp, Nonsuch Island, Aug. 18, 1931 (No. 311,437) and is in the collections of the Department of Tropical Research of the New York Zoological Society. There is another specimen from the same locality, Aug. 19, 1931 (No. 311,487).

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Family Typhloscolecidae.

Travisiopsis Levinsen.

Travisiopsis atlantica n. sp.

(Figs. 30-33).

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The type is 24 mm. long and has a body width of 4 mm. Thirty somites carry the flattened cirri. The prostomium (Fig. 30) is bluntly conical but has a short filamentous tip and its basal diameter is about equal to its length. It is largely covered on either side by the overlapping 1st cirrus. On the posterior border of the 1st somite is a pair of tentacular processes which are about as long as the 2nd somite and in the preserved material extend almost vertically. The mouth is a relatively large circular opening.

The first 3 pairs of cirri are notopodial but beginning with the 4th they occur on both noto- and neuropodia and this arrangement is continued throughout the body. The first pair are nearly circular in outline but later

ones become broadly ovate with flattened points of attachment and narrow points on the outer margins (Fig. 31). A ring of 5 narrower cirri surround the anal opening. These (Fig. 32) are carried on a prominent cirrophore and are asymmetrically lanceolate in outline but have blunt apices. From the base to the apex and nearer one margin is a band of much firmer texture than elsewhere in the cirrus and must give it a considerable degree of rigidity. A much smaller band occurs in the other cirri. When in position, because they extend stiffly out from the posterior end while the other cirri are apt to lie more closely appressed against the sides of the body, the anal cirri appear to be much larger than the others. Figs. 31 and 32, drawn to the same scale, show this to be erroneous. The cirrus from which Fig. 32 was drawn was cut from the type which was the only one in which these anal cirri were not badly wrinkled. The setae in the smaller specimens are more easily seen than in the larger. They are few in number in a single tuft, stout and sharp pointed (Fig. 33).

The type was collected in Net 1,151, 600 fathoms, Aug. 8, 1931 (No. 311,116), and is in the collections of the Department of Tropical Research of the New York Zoological Society. Others were taken in the following nets: Net 798, 600 fathoms, July 15, 1930 (No. 30,522); Net 860, 600 fathoms, Sept. 8, 1930 (No. 30,793); Net 866, 700 fathoms, Sept. 10, 1930 (No. 30,830), and Net 929, 700 fathoms, Sept. 20, 1930 (No. 301,134).

Travisiopsis sp. ?

These are smaller than *T. atlantica* and their systematic position is doubtful, though they may be the young of that species. Only a few cirri are preserved. The setae are similar to those of *T. atlantica* but especially in the posterior portion of the body are more prominent and extend to a considerable distance from the body wall.

Collected in Net 693, 900 fathoms, June 12, 1930 (No. 30,182); Net 726, 800 fathoms, June 26 (No. 30,258); Net 893, 900 fathoms, June 15, 1930 (No. 301,058); Net 917, 600 fathoms, Sept. 19, 1930 (No. 30,964). Fragments too much injured for any identification were taken in two other nets (Nos. 30,964; 30,258).

Family Cirratulidae.
Cirratulus Lamarck.
Cirratulus multicirratus n. sp.
(Figs. 34, 35).

The type and only specimen is 60 mm. long and has a body width of 4 mm. in the widest portion. All except the first two somites are very short. Cirri begin on the 1st setigerous somite and continue nearly to the extreme posterior end. In the anterior region they occur on every somite but toward the posterior end there are considerable gaps in the series, though considering the fact that they may appear in several consecutive somites and then be lacking from another set, it is possible that their absence means a loss rather than a normal condition. The prostomium (Fig. 34) is bluntly conical and is so much fused with the 1st somite and this latter with the 2nd that it is difficult to distinguish the boundaries, except for faint lines on the lateral surfaces. The first two somites together are about as long as the prostomium, while the 3rd somite is hardly more than half as long as the second. Posteriorly there is an increase in somite length. The body narrows decidedly toward the posterior end and the pygidium is cylindrical with an oval, dorsally directed anus. Setae begin on the 3rd somite as capillary structures in both parapodial lobes. Hooks (Fig. 35) appear in the ventral ramus by the end of the anterior quarter of the body and pos-

terior to the middle of the body they are the only ones represented in the parapodia.

The first cirri are small but in the region from the 10th to the 20th somites they are much longer, forming a noticeable bunch. Later they again become smaller, but the length is always many times the body width. On either side of the dorsal surface of the 5th setigerous somite is a tuft of 6-8 gills smaller than the neighboring cirri. They are bunched close to the margins on either side, leaving the greater part of the dorsal surface uncovered.

The type was collected on mud flats on St. David's Island, Bermuda, Aug. 17, 1931 (No. 311,398) and is in the collections of the Department of Tropical Research of the New York Zoological Society.

Audouinea Quatrefages.
Audouinea pygidia n. sp.
(Figs. 22, 23)

Two specimens of which the larger is 22 mm. long and 2.5 mm. in greatest width. The most characteristic external feature is that the posterior end over a region of some twenty somites is entirely colorless, while immediately in front of this an area of about the same number of somites is colored black. If found in only one individual the colorless region might reasonably be regarded as a regenerating portion, but since it is present in both it is obviously a normal condition. The remainder of the body is light brown in color, with a tendency toward a darker tone anteriorly, but the extreme anterior end is lighter.

The prostomial width much exceeds its breadth and its margins merge into those of the 1st somite (Fig. 22), the two making an area whose basal width is about twice its length and except that the base is a trifle too wide, is hemispherical in outline. The second somite is shorter at the margins than on the dorsal surface where it expands to project posteriorly into the anterior margin of the 3rd somite. The 3rd somite is twice as long as the 2nd. Later somites are all very short as compared with their width, but behind the first eighth of the body this proportion slightly increases. Capillary setae first appear in the 4th somite and hooks occur in the neuropodia after about the 20th somite, while only capillary ones are found in the notopodia.

Apparently most of the dorsal cirri have been lost from both specimens since their distribution is different in the two, but occur in scattering fashion to the extreme posterior end. In the type there is a small one on the 3rd somite, a much larger one on the 6th and an irregular distribution farther back. A very large dorsal gill was located on the 5th somite in the type. This was broken away by an accident, but from the scars it seems certain that originally there were two of these on either side of the body, lying on the 5th and 6th somites.

The setae of anterior somites and of the notopodium in all somites are capillary, numerous in each tuft, long, slender and sharp pointed. The hooks are dark brown in color, curved to an acute point at the end and protrude for a considerable distance from the body surface (Fig. 23).

The paratypes were collected from tidepools on Nonsuch Island, Sept. 12, 1930 (No. 301,675), and are in the collections of the Department of Tropical Research of the New York Zoological Society.

Dodecaceria Oersted.
Dodecaceria sp. ?

Fragments too poorly preserved for identification, collected in tidepools, Nonsuch Island, April 23, 1929 (No. 2,945) and Aug. 16, 1931 (No. 311,357).

Family Sabellidae.
Protulides Webster.
Protulides elegans Webster.

Protulides elegans Webster, 1884, pp. 325, 326; Pl. 10, Figs. 63-74.
Collected from reef, Castle Harbor, Aug. 15, 1931 (No. 311,335). One specimen.

Vermilia Lamarck.
Vermilia glandulata n. sp.
(Figs. 36-39).

The type has a total length of 13 mm. of which the thorax and branchiae each make up 3 mm. The opercular stalk is as long as the branchiae and carries a large globular operculum. There are 13 branchiae on the right and 12 plus the opercular stalk on the left. The opercular stalk (Fig. 36) is divided into about twenty rings of which the terminal is the largest. The operculum is a globular body which on its outer surface is drawn out into a terminal portion which was covered by a white limestone deposit. This terminal portion is brown in color and marked by circular brown lines darker than the general surface. The remainder of the body is colorless. The gill filaments are in two rows and are very short, hardly longer than the diameter of the main branchial stem.

There are 7 somites in the thorax. The collar is in the form of a broad wing on either side and on its anterior margin its breadth is equal to the body width. Its lateral margins slope to meet the body wall at the level of the 5th setigerous somite. The dorsal collar lobe is distinct from the lateral ones and extends anteriorly to cover the bases of the branchiae.

The abdominal somites are very short and a noticeable feature is that on the ventral surfaces of the posterior twenty are ventral shields which are more prominent in one of the two specimens than in the other.

Setae of the simple type occur in the 1st setigerous somite and are of two forms. The first (Fig. 37) are very slender, long and sharp pointed; the second (Fig. 38) are fully four times as broad as the first and are marked by fine diagonal striations. Similar setae are found in the other somites throughout the body, but in the abdomen they are very short and do not protrude far from the body surface. At the extreme posterior end is a series of setae like those of Fig. 37 in general outline, but very long. The uncini of thorax and of abdomen are alike, each (Fig. 39) having a basal knob and 20 fine teeth.

In its annulated opercular stalk this species resembles Schmarda's *V. annulata* described originally from Jamaica, but the description revised and enlarged by Ehlers (1887, p. 308, Pl. 58, Figs. 12-16; Pl. 59, Figs. 1-3), but they differ in the form of the operculum, in the number of the branchiae and in the shape of the uncini.

The tube has the form characteristic of this genus, a heavy shell marked by longitudinal lines.

The type was collected at Gurnet's Rock, 35 feet deep, Aug. 19, 1931 (No. 311,480), and is in the collections of the Department of Tropical Research of the New York Zoological Society. Another specimen was taken at Castle Harbor, reef, Aug. 16, 1931 (No. 311,347).

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EXPLANATION OF THE PLATES.

PLATE I.

Eunoe purpurea

Fig. 1. Head x 7.
Fig. 2. Sixteenth parapodium x 14.
Fig. 3. Ventral seta x 65.
Fig. 4. Ventral seta x 65.
Fig. 5. Large dorsal seta x 85.
Fig. 6. Elytron x 10.

Drieschia atlantica

Fig. 7 Head x 10.
Fig. 8. Parapodium x 45.
Fig. 9. Ventral seta x 185.

Eupholoë nuda

Fig. 10. Head x 16.
Fig. 11. Parapodium x 45.
Fig. 12. Notopodial seta x 185.
Fig. 13. Neuropodial seta x 185.
Fig. 14. Second form of neuropodial seta x 185.

PLATE II.

Nereis bairdii

Fig. 15. Parapodium of heteronereis phase x 45.

Nereis glandulata

Fig. 16. Parapodium from anterior portion of body in heteronereis phase.
Fig. 17. Parapodium from posterior portion in heteronereis phase.

Tomopteris longisetis

Fig. 18. Ventral view of head x 5.
Fig. 19. Parapodium x 5.
Fig. 20. Uncolored rosette x 45.
Fig. 21. Colored rosette x 68.

Audouinea pygidia

Fig. 22. Head x 10.
Fig. 23. Seta x 185.

Ammotrypane bermudiensis

Fig. 24. Anterior end x 5.
Fig. 25. Anal tube x 6.
Fig. 26. Parapodium x 85.

Polyophthalmus incertus

Fig. 27. Dorsal view of head x 45.
Fig. 28. Ventral view of head x 45.
Fig. 29. Pygidium x 45.

PLATE III.

Travisiopsis atlantica

Fig. 30. Head x 23.
Fig. 31. Cirrus from body somite x 45.
Fig. 32. Anal cirrus x 45.
Fig. 33. Seta x 68.

Cirratulus multicirratus
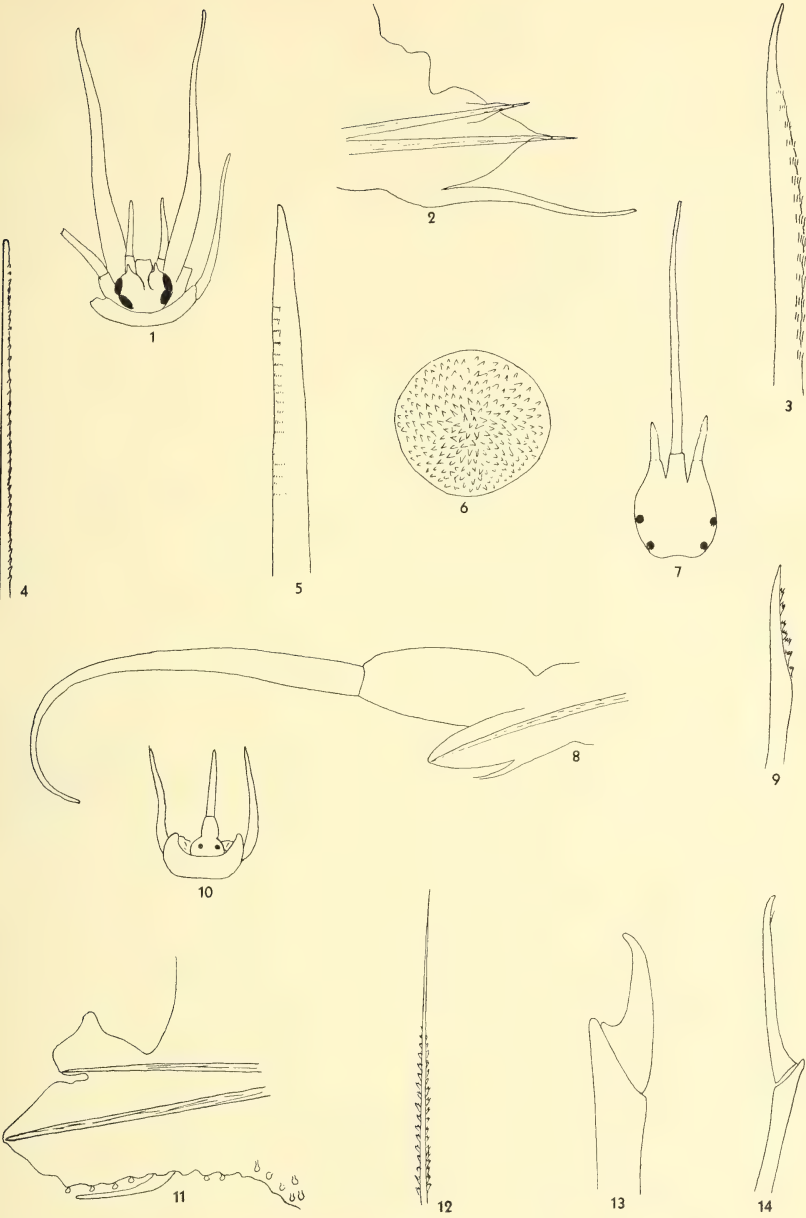
Fig. 34. Head x 10.
Fig. 35. Hook x 185.

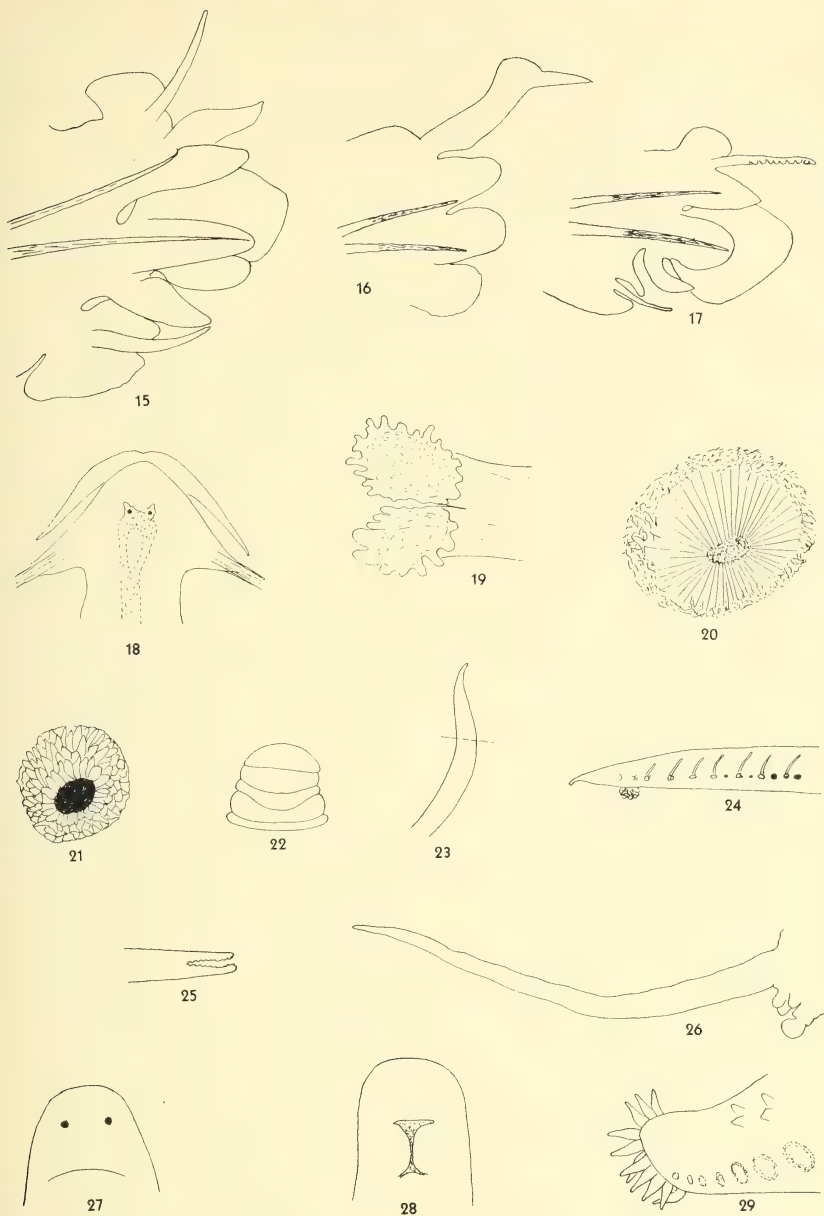*Vermilia glandulata*

Fig. 36. Operculum x 4.
Fig. 37. Slender seta x 185.
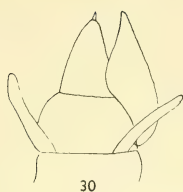Fig. 38. Larger seta x 185.
Fig. 39. Uncinus x 250.

PLATE I.

POLYCHAETOUS ANNELIDS FROM THE VICINITY OF
NONSUCH ISLAND, BERMUDA.

PLATE II.

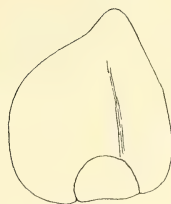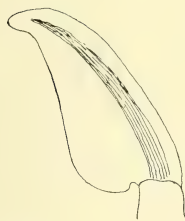POLYCHAETOUS ANNELIDS FROM THE VICINITY OF
NONSUCH ISLAND, BERMUDA.

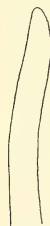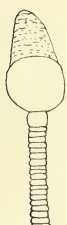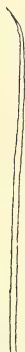POLYCHAETOUS ANNELIDS FROM THE VICINITY OF
NONSUCH ISLAND, BERMUDA.

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS

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NEW YORK ZOOLOGICAL SOCIETY

VOLUME XXI

Part 2

Numbers 3-11

CONTENTS

3.

Bermuda Oceanographic Expeditions. Individual Nets and Data, 1932-1935[1].

WILLIAM BEEBE.

Director, Department of Tropical Research,
New York Zoological Society.

The absence of nets during 1932 was due to constant and intensive operation of the bathysphere dives.

The lists and data of preceding nets, from Nos. 1 to 1350, together with an account of previous oceanographic investigations near Bermuda, description of the collecting apparatus, methods of trawling, and details of the locality chosen for study, are to be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3.

All foot nets are diatom nets, of No. 20 standard bolting cloth. Other nets are standard Michel Sars patterns, of 2XX bolting cloth.

Nets marked with an asterisk (*) were drawn in Castle Harbor, inside of the outer reefs. All others were drawn out at sea.

INDIVIDUAL NETS AND DATA

Net No.	Type of Net	Depth		Date 1933	Start of Haul	Duration of Haul		Direction of Haul	Weather	Wind		Sea
		Fathoms	Metres			Hrs.	Mins.			Direction	Force	
				Sept.								
1351	Metre	0	0	4	8:05 p.m.	—	20	E	No moon	0	0	Calm
*1352	Foot	0	0	14	7:45	—	45	E	No moon	0	0	Calm
*1353	Foot	0	0	15	7:45	—	50	E	No moon	SE	4	Calm
*1354	Foot	0	0	17	10:00 a.m.	1	0	E	Overcast	SW	5	Choppy
*1355	Foot	0	0	17	7:35 p.m.	1	0	E	No moon	WSW	5	Choppy
*1356	Foot	0	0	17	7:35	1	0	E	No moon	WSW	5	Choppy
*1357	½-Metre	0	0	18	8:00	—	50	W	No moon	SW	3	Choppy
*1358	Foot	0	0	18	8:00	—	50	W	No moon	SW	3	Choppy
*1359	Foot	0	0	18	8:00	—	50	E	No moon	SW	3	Choppy
*1360	Foot	0	0	19	8:00	1	0	E	No moon	SW	5	Choppy
*1361	Foot	0	0	19	8:00	1	0	E	No moon	SW	5	Choppy
*1362	½-Metre	0	0	19	8:00	1	0	E	No moon	SW	5	Choppy
1363	Metre	0	0	20	8:00	1	0	N	No moon	SW	2	Choppy
1364	Foot	0	0	20	8:00	1	0	N	No moon	SW	2	Choppy
*1365	½-Metre	0	0	22	8:00	1	0	E	No moon	WSW	4	Choppy
*1366	Foot	0	0	22	8:00	1	0	E	No moon	WSW	4	Choppy
*1367	Foot	0	0	22	8:00	1	0	E	No moon	WSW	4	Choppy

INDIVIDUAL NETS AND DATA (*continued*)

Net No.	Type of Net	Depth		Date 1933	Start of Haul	Duration of Haul		Direction of Haul	Weather	Wind		Sea
		Fathoms	Metres			Hrs.	Mins.			Direction	Force	
				Sept.								
*1368	Foot	0	0	23	8:00	—	30	W	No moon	0	0	Calm
*1369	Foot	0	0	23	8:00	—	30	W	No moon	0	0	Calm
1370	½-Metre	0	0	24	5:00 a.m.	—	30	E	No moon	0	0	Calm
1371	Metre	0	0	24	5:00	1	0	E	No moon	0	0	Calm
1372	½-Metre	0	0	25	5:30	—	30	E	Clear	NE	1	Calm
1373	½-Metre	0	0	25	6:00	—	30	E	Clear	NE	1	Calm
1374	Metre	0	0	25	5:30	—	30	E	Clear	NE	1	Calm
1375	Metre	0	0	25	6:00	—	30	E	Clear	NE	1	Calm
*1376	Foot	0	0	26	7:50	—	35	W	Moonlight	0	0	Calm
*1377	Foot	0	0	26	7:50	—	35	W	Moonlight	0	0	Calm
1378	Metre	0	0	27	4:45	—	20	E	No moon	0	0	Calm
1379	Metre	0	0	27	5:05	—	20	E	No moon	0	0	Calm
1380	Metre	0	0	27	5:25	—	20	E	No moon	0	0	Calm
1381	Metre	0	0	27	5:45	—	20	E	Clear	0	0	Calm
1382	½-Metre	0	0	27	4:45	—	20	E	No moon	0	0	Calm
1383	½-Metre	0	0	27	5:05	—	20	E	No moon	0	0	Calm
*1384	Foot	1	2	27	3:00 p.m.	—	15	W	Clear	0	0	Calm
1385	Metre	0	0	28	4:30 a.m.	—	20	E	No moon	ESE	3	Choppy
1386	Metre	0	0	28	4:50	—	20	E	No moon	ESE	3	Choppy
1387	Metre	0	0	28	5:10	—	25	E	No moon	ESE	3	Choppy
1388	Metre	0	0	28	5:35	—	25	W	Clear	ESE	3	Choppy
1389	½-Metre	0	0	28	4:30	—	20	E	No moon	ESE	3	Choppy
1390	½-Metre	0	0	28	4:50	—	20	E	No moon	ESE	3	Choppy
				Oct.								
*1391	Foot	1	2	2	3:30 p.m.	—	30	W	Clear	SE	3	Choppy
1392	Foot	0	0	4	7:25	—	20	N	Moonlight	SE	4	Choppy
1393	Foot	0	0	4	7:45	—	15	N	Moonlight	SE	4	Choppy
1394	Foot	0	0	4	8:00	—	25	S	Moonlight	SE	4	Choppy
1395	Foot	0	0	4	8:00	—	25	S	Moonlight	SE	4	Choppy
*1396	Foot	0	0	7	7:30	—	45	W	No moon	SW	4	Choppy
*1397	Foot	0	0	7	7:30	—	45	W	No moon	SW	4	Choppy
1398	Metre	0	0	9	7:45	—	20	E	No moon	NE	3	Choppy
1399	Metre	0	0	9	8:00	—	20	W	No moon	NE	3	Choppy
1400	Foot	0	0	9	7:45	—	20	E	No moon	NE	3	Choppy
1401	Foot	0	0	9	8:10	—	20	W	No moon	NE	3	Choppy
1402	Metre	0	0	10	8:20	—	20	NxE	No moon	0	0	Calm
1403	Metre	0	0	10	8:40	—	20	NxE	No moon	0	0	Calm
1404	Metre	0	0	10	9:00	—	20	NxE	No moon	0	0	Calm
1405	½-Metre	0	0	10	8:20	—	20	NxE	No moon	0	0	Calm
1406	½-Metre	0	0	10	8:40	—	20	NxE	No moon	0	0	Calm
1407	½-Metre	0	0	10	9:00	—	20	NxE	No moon	0	0	Calm
1408	Metre	0	0	11	7:45	—	20	ExN	No moon	SE	3	Choppy
1409	Metre	0	0	11	8:05	—	20	ExN	No moon	SE	3	Choppy
1410	Metre	0	0	11	8:25	—	20	WxS	No moon	SE	3	Choppy
1411	½-Metre	0	0	11	7:45	—	20	ExN	No moon	SE	3	Choppy
1412	½-Metre	0	0	11	8:05	—	20	ExN	No moon	SE	3	Choppy
1413	Metre	0	0	12	8:15	—	20	E	No moon	SE	3	Choppy
1414	Metre	0	0	12	8:35	—	20	E	No moon	SE	3	Choppy
1415	Metre	0	0	12	8:55	—	20	W	No moon	SE	3	Choppy
1416	½-Metre	0	0	12	8:15	—	20	E	No moon	SE	3	Choppy
1417	½-Metre	0	0	12	8:35	—	20	E	No moon	SE	3	Choppy
1418	Metre	0	0	14	7:40	—	20	E	No moon	NExN	2	Calm
1419	Metre	0	0	14	8:03	—	20	E	No moon	NExN	2	Calm
1420	Metre	0	0	14	8:25	—	20	W	No moon	NExN	2	Calm
1421	½-Metre	0	0	14	7:40	—	20	E	No moon	NExN	2	Calm
1422	½-Metre	0	0	14	8:03	—	20	E	No moon	NExN	2	Calm
1423	½-Metre	0	0	14	8:25	—	20	W	No moon	NExN	2	Calm
1424	Metre	0	0	18	7:40	—	20	ExN	No moon	NE	1	Calm

INDIVIDUAL NETS AND DATA (*continued*)

Net No.	Type of Net	Depth Fathoms	Depth Metres	Date 1933	Start of Haul	Duration Hrs.	Duration Mins.	Direction of Haul	Weather	Wind Direction	Wind Force	Sea
				Oct.								
1425	½-Metre	0	0	18	7:40	—	20	ExN	No moon	NE	1	Calm
1426	Metre	0	0	18	8:05	—	20	WxS	No moon	NE	1	Calm
1427	½-Metre	0	0	18	8:05	—	20	WxS	No moon	NE	1	Calm
1428	Metre	0	0	18	8:30	—	20	WxS	No moon	NE	1	Calm
1429	½-Metre	0	0	18	8:30	—	20	WxS	No moon	NE	1	Calm
*1430	Metre	0	0	20	2:15	—	20	S	Clear	ExN	4	Choppy
*1431	Foot	0	0	20	2:15	—	20	S	Clear	ExN	4	Choppy
*1432	Metre	0	0	20	2:40	—	20	S	Clear	ExN	4	Choppy
*1433	Foot	0	0	20	2:40	—	20	S	Clear	ExN	4	Choppy
*1434	Metre	0	0	20	3:15	—	15	N	Clear	ExN	4	Choppy
*1435	Foot	0	0	20	3:15	—	15	N	Clear	ExN	4	Choppy
*1436	Foot	0	0	21	7:15	—	20	W	Overcast	ESE	5	Choppy
*1437	½-Metre	0	0	25	7:15	—	30	W	Moonlight	SW	2	Calm
*1438	½-Metre	0	0	27	8:00	—	30	W	Overcast	ESE	5	Choppy
1439	Metre	0	0	28	2:15	—	20	E	Clear	SW	4	Choppy
1440	Foot	0	0	28	2:15	—	20	E	Clear	SW	4	Choppy
1441	Metre	0	0	28	2:40	—	20	W	Clear	SW	4	Choppy
1442	Foot	1½	2¼	28	2:40	—	20	W	Clear	SW	4	Choppy
1443	Metre	0	0	28	3:15	—	15	W	Clear	SW	4	Choppy
1444	Foot	1½	2¼	28	3:15	—	15	W	Clear	SW	4	Choppy
				Nov.								
*1445	Foot	0	0	1	7:30	—	30	W	Moonlight	0	0	Calm
1446	Metre	0	0	2	4:45 a.m.	—	20	E	Moonlight	NNE	4	Choppy
1447	Foot	0	0	2	4:45	—	20	E	Moonlight	NNE	4	Choppy
1448	Metre	0	0	2	5:10	—	20	E	Moonlight	NNE	4	Choppy
1449	½-Metre	0	0	2	5:10	—	20	E	Moonlight	NNE	4	Choppy
1450	Metre	0	0	2	5:40	—	20	W	Overcast	NNE	4	Choppy
1451	½-Metre	0	0	2	5:40	—	20	W	Overcast	NNE	4	Choppy
1452	Metre	0	0	11	2:45 p.m.	—	20	E	Overcast	ENE	5	Rough
1453	Metre	0	0	11	3:10	—	20	E	Overcast	ENE	5	Rough
1454	Metre	0	0	11	3:35	—	20	S	Overcast	ENE	5	Rough
1455	½-Metre	1	2	11	2:45	—	20	E	Overcast	ENE	5	Rough
1456	Foot	1	2	11	3:10	—	20	E	Overcast	ENE	5	Rough
1457	½-Metre	1	2	11	3:35	—	20	S	Overcast	ENE	5	Rough
1458	Metre	0	0	21	7:45	—	25	E	Moonlight	0	0	Calm
1459	Metre	0	0	21	8:15	—	25	E	Moonlight	0	0	Calm
1460	Foot D.	0	0	21	7:45	—	25	E	Moonlight	0	0	Calm
1461	½-Metre	0	0	21	8:15	—	25	E	Moonlight	0	0	Calm
				1934 May								
*1462	½-Metre	0	0	18	8:10 p.m.	—	20	E	Overcast	SE	5	Choppy
*1463	½-Metre	0	0	20	9:10 a.m.	—	20	E	Clear	0	0	Calm
*1464	½-Metre	0	0	20	9:35	—	20	E	Clear	0	0	Calm
1465	½-Metre	0	0	21	11:45	—	15	S	Clear	0	0	Calm
1466	½-Metre	0	0	22	3:30 p.m.	—	10	S	Clear	—	—	Rough
*1467	½-Metre	0	0	26	9:15 a.m.	—	15	S	Clear	S	3	Choppy
1468	½-Metre	0	0	26	9:35	—	20	S	Clear	S	3	Choppy
*1469	½-Metre	0	0	31	8:50	—	20	S	Overcast	SW	3	Choppy
*1470	½-Metre	½	¼	31	9:20	—	20	S	Overcast	SW	3	Choppy
*1471	Foot	1	2	31	8:50	—	20	S	Overcast	SW	3	Choppy
*1472	Foot	0	0	31	9:20	—	20	S	Overcast	SW	3	Choppy
				June								
1473	½-Metre	0	0	1	3:25 p.m.	—	20	E	Overcast	WxN	3	Swell
1474	½-Metre	1	2	1	3:50	—	20	W	Overcast	WxN	3	Swell
1475	Foot	1	2	1	3:25	—	20	E	Overcast	WxN	3	Swell
1476	Foot	0	0	1	3:50	—	20	W	Overcast	WxN	3	Swell
*1477	½-Metre	0	0	8	10:30 a.m.	—	40	S	Clear	SW	2	Choppy

INDIVIDUAL NETS AND DATA (*continued*)

Net No.	Type of Net	Depth Fathoms	Depth Metres	Date 1934	Start of Haul	Duration of Haul Hrs.	Duration of Haul Mins.	Direction of Haul	Weather	Wind Direction	Wind Force	Sea
				July								
1478	Foot	0	0	2	3:00 p.m.	—	40	E	Clear	SW	4	Choppy
1479	½-Metre	0	0	2	3:00	—	40	E	Clear	SW	4	Choppy
1480	½-Metre	0	0	4	11:00 a.m.	—	20	S	Clear	0	0	Choppy
1481	½-Metre	0	0	12	3:00 p.m.	—	40	S	Clear	SW	3	Choppy
1482	Foot	0	0	12	3:00	—	40	S	Clear	SW	3	Choppy
				Aug.								
1483	Metre	0	0	20	10:30 a.m.	—	30	NW	Clear	0	0	Calm
				Sept.								
1484	Metre	0	0	7	9:30	—	20	E	Clear	0	0	Calm
1485	Metre	0	0	7	9:52	—	10	E	Clear	0	0	Calm
1486	Metre	0	0	9	2:40 p.m.	—	20	E	Clear	0	0	Calm
1487	Metre	0	0	9	3:01	—	15	E	Clear	0	0	Calm
1488	Metre	0	0	16	3:00	—	20	E	Clear	0	0	Calm
1489	Metre	0	0	17	2:20	—	20	E	Clear	0	0	Calm
1490	Metre	0	0	18	3:20	—	20	E	Clear	0	0	Calm
1491	Metre	0	0	18	3:44	—	20	E	Clear	0	0	Calm
1492	Metre	0	0	26	3:20	—	20	E	Clear	0	0	Calm
1493	Metre	0	0	26	3:40	—	20	E	Clear	0	0	Calm
1494	Metre	0	0	28	2:40	—	20	SE	Clear	ESE	5	Rough
				Oct.								
*1495	Metre	½	¼	6	3:15	—	15	E	Overcast	—	4	Choppy
1496	Metre	0	0	9	2:45	—	20	SE	Clear	NE	3	Rough
1497	Metre	0	0	9	3:10	—	15	NW	Clear	NE	3	Rough
*1498	½-Metre	0	0	9	8:00	—	20	E	No moon	NE	3	Choppy
1499	Metre	0	0	13	3:30	—	15	E	Clear	SW	3	Rough
1500	Metre	0	0	14	3:25	—	20	E	Overcast	NE	3	Choppy
				July								
1501	Metre	400	732	25	9:40 a.m.	4	03	SSE	Clear	NNE	4	Choppy
1502	Metre	500	914	25	9:40	4	03	SSE	Clear	NNE	4	Choppy
1503	Metre	600	1097	25	9:40	4	03	SSE	Clear	NNE	4	Choppy
1504	Metre	700	1280	25	9:40	4	03	SSE	Clear	NNE	4	Choppy
1505	Metre	800	1463	25	9:40	4	03	SSE	Clear	NNE	4	Choppy
1506	Metre	900	1646	25	9:40	4	03	SSE	Clear	NNE	4	Choppy
				Aug.								
1507	Metre	50	92	14	12:16 p.m.	2	30	SSE	Clear	SW	2	Calm
1508	Metre	100	183	14	12:16	2	30	SSE	Clear	SW	2	Calm
1509	Metre	200	366	14	12:16	2	30	SSE	Clear	SW	2	Calm
1510	Metre	300	549	14	12:16	2	30	SSE	Clear	SW	2	Calm
1511	Metre	400	732	14	12:16	2	30	SSE	Clear	SW	2	Calm
1512	Metre	500	914	14	12:16	2	30	SSE	Clear	SW	2	Calm
1513	Tangle	1350	2470	14	9:30 a.m.	—	36	SSE	Clear	SW	2	Calm
				Oct.								
1514	Metre	0	0	15	4:00 p.m.	—	20	E	Clear	0	0	Calm
1515	Metre	0	0	15	3:35	—	20	E	Clear	0	0	Calm
1516	Metre	0	0	16	3:30	—	20	E	Overcast	0	0	Calm
1517	Metre	0	0	17	4:00	—	30	E	Overcast	NE	3	Rough
				1935 June								
1518	Metre	0	0	7	9:30 a.m.	—	44	E	Overcast	E	3	Choppy
1519	Metre	0	0	12	9:40	—	20	S	Clear	SW	3	Swell
1520	Metre	0	0	15	9:10	—	30	E	Clear	S	2	Choppy
1521	Metre	0	0	15	9:50	—	10	W	Clear	S	2	Choppy
*1522	Metre	0	0	19	2:40 p.m.	—	20	W	Clear	SW	3	Choppy
1523	Metre	0	0	24	2:20	—	50	E	Clear	SSE	3	Choppy
1524	Metre	0	0	29	9:40 a.m.	—	35	E	Clear	E	3	Swell
				July								
1525	Metre	0	0	3	9:10	—	40	E	Overcast	SE	3	Rough

INDIVIDUAL NETS AND DATA (*continued*)

Net No.	Type of Net	Depth Fath-oms	Depth Me-tres	Date 1935	Start of Haul	Duration of Haul Hrs.	Duration of Haul Mins.	Direction of Haul	Weather	Wind Direction	Wind Force	Sea
				July								
1526	Metre	0	0	7	2:10 p.m.	—	20	S	Clear	SE	3	Choppy
1527	Metre	0	0	9	8:20	—	25	E	Moonlight	SE	2	Calm
1528	½-Metre	0	0	12	11:15 a.m.	—	10	S	Clear	SW	3	Choppy
1529	½-Metre	100	183	15	2:36 p.m.	1	0	S	Clear	SE	3	Choppy
1530	Metre	0	0	15	4:00	—	10	S	Clear	SE	3	Choppy
1531	Metre	0	0	19	10:11 a.m.	—	15	S	Clear	SE	3	Rough
1532	½-Metre	125	228	20	9:19	1	0	SE	Clear	SE	2	Calm
1533	Metre	0	0	20	10:26	—	10	SE	Clear	SE	2	Calm
1534	½-Metre	225	410	22	2:45 p.m.	1	0	SExS	Clear	SE	1	Calm
1535	Metre	0	0	22	4:14	—	10	SExS	Clear	SE	1	Calm
1536	½-Metre	455	828	23	9:28 a.m.	1	30	SE	Clear	SE	1	Calm
1537	Metre	0	0	23	9:45	1	05	SE	Clear	SE	1	Calm
1538	½-Metre	300	549	24	2:25 p.m.	1	02	SE	Clear	SE	1	Calm
1539	Metre	0	0	24	4:04	—	10	SE	Clear	SE	1	Calm
				Aug.								
1540	Metre	0	0	4	2:50	—	20	E	Clear	SE	4	Choppy
1541	Metre	0	0	7	2.00	—	25	E	Clear	SE	2	Calm
1542	Metre	0	0	24	2:30	—	24	S	Overcast	SW	3	Rough
1543	Metre	0	0	26	2:30	—	23	E	Overcast	SW	3	Choppy
1544	Metre	0	0	27	9:25 a.m.	—	30	E	Squally	SW	3	Choppy
1545	Metre	0	0	28	10:00	—	30	E	Clear	S	1	Calm
1546	Metre	0	0	31	10:00	—	27	E	Clear	S	4	Rough
				Sept.								
1547	Metre	0	0	1	5:00	—	24	E	Clear	SSE	2	Choppy
1548	Metre	0	0	1	5:32	—	12	E	Clear	SSE	2	Choppy
1549	Metre	0	0	3	9:00	—	30	E	Clear	S	2	Calm
1550	Metre	0	0	7	2:00 p.m.	—	30	E	Clear	N	4	Rough
1551	Metre	0	0	9	9:10 a.m.	—	30	E	Clear	SW	4	Choppy
1552	Metre	0	0	13	9:00	—	20	E	Clear	SW	4	Rough
1553	Metre	0	0	13	9:45	—	10	W	Clear	SW	4	Choppy
1554	Metre	0	0	16	2:20 p.m.	—	30	S	Clear	SW	2	Choppy
*1555	Metre	0	0	16	3:10	—	10	N	Clear	SW	2	Calm
1556	Metre	0	0	17	9:10 a.m.	—	30	E	Clear	NW	2	Choppy
1557	Metre	0	0	20	7:55 p.m.	—	30	E	No moon	SE	4	Choppy
1558	Metre	0	0	22	5:05 a.m.	—	30	E	Moonlight	0	0	Calm
1559	Metre	0	0	28	9:27	—	10	W	Overcast	SW	2	Choppy
1560	Metre	1	2	28	9:15	—	10	E	Overcast	SW	2	Choppy
1561	Metre	0	0	28	9:00	—	10	E	Overcast	SW	2	Choppy
				Oct.								
1562	Metre	0	0	2	9:23	—	10	E	Overcast	SSW	4	Rough
1563	Metre	1	2	2	9:10	—	10	W	Overcast	SSW	4	Rough
1564	Metre	0	0	6	2:05 p.m.	—	10	E	Overcast	SW	2	Swell
1565	Metre	0	0	6	2:17	—	10	E	Overcast	SW	2	Swell
1566	Metre	1	2	6	2:30	—	10	W	Overcast	SW	2	Swell
1567	½-Metre	0	0	12	11:21 a.m.	—	10	SxE	Clear	SW	2	Calm
1568	½-Metre	1.8	3	12	11:08	—	10	SxE	Clear	SW	2	Calm
1569	½-Metre	5	9.2	12	10:15	—	10	SxE	Clear	SW	2	Calm
1570	½-Metre	8.2	15.3	12	10:28	—	10	SxE	Clear	SW	2	Calm
1571	½-Metre	12.5	23	12	10:55	—	10	SxE	Clear	SW	2	Calm
1572	½-Metre	17	31	12	10:41	—	10	SxE	Clear	SW	2	Calm
1573	½-Metre	0	0	12	11:52	—	10	NNW	Clear	SW	2	Calm
*1574	½-Metre	0	0	12	12:20	—	10	N	Clear	SW	1	Calm

4.

Plankton of the Bermuda Oceanographic Expeditions[1]. I.

G. H. WAILES.

City Museum, Vancouver, B. C.

INTRODUCTION BY WILLIAM BEEBE.

The matter in this series of papers is a continuation of the oceanographic work carried on by myself and my staff of the Department of Tropical Research of the New York Zoological Society, off the island of Nonsuch, Bermuda. Full details of this investigation, together with complete data of hauls, may be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3, and Volume XXI, Number 3. I have thought it worth while to add a few paragraphs of the most pertinent data.

LOCALITY.

The area in which the fifteen hundred-odd nets have been drawn is roughly circular and eight miles in diameter. Observations by means of the two light-houses, Gibb's Hill and St. Davids, have made it possible to get accurate sights at the beginning and end of each individual haul. To give the location with more exactness: the eight-mile circle under consideration has its center at 32° 12' N. Lat. and 64° 36' W. Long., which point is 160 degrees by the compass, or south-south-east of Nonsuch. Its horizontal boundaries are as follows:

Northern rim: 32° 16' N. Lat.
Southern rim: 32° 8' N. Lat.
Eastern rim: 64° 31' 20" W. Long.
Western rim: 64° 40' 40" W. Long.

At no place is its bottom less than 1,000 fathoms in depth. It slopes rather rapidly in the northeastern corner to 1,357 fathoms, and along its southern border is between 1,400 and 1,500 fathoms deep. My first deep dive in the bathysphere, of 803 feet, was in the southwest sector, and the later ones of 1,426, 2,200, 2,510 and 3,028 feet were all near the northern rim.

METHODS.

The deep-sea trawling has all been done from the aft deck of the tug *Gladisfen.* When the rim of the imaginary cylinder has been reached the weight at the end of the wire is put overboard and the cable gradually paid out at a 30° angle. Six nets are usually attached, 1-metre nets of standard oceanographic design, 20 feet in length, with the posterior portion of No. 2

bolting silk and the upper part of No. 0 bolting silk. In addition to this there is the usual collar of shrimp netting, with 10 mm. mesh.

These nets are placed along the cable at measured intervals so that at a 30° angle they will haul 100 fathoms apart, usually from the surface to 500 fathoms, or from 500 to a depth of 1,000 fathoms. After as long a haul as the time will permit the nets are pulled in and the contents taken ashore to the laboratory for sorting and study.

The exact depth at which the nets are drawn is assured by the use of a special bathygraph pressure gauge which registers the entire course of the lowest net from surface to greatest depth and back to surface again, together with the duration of the haul.

All of the deep-sea hauls are made with horizontal tow nets unprovided with closing apparatus. After the first few hauls were made off Bermuda at deep levels, it was found advisable, owing to the relatively small amount of captured animal life, to extend the length of towing time for the nets up to periods of four to six hours. Experience on the *Arcturus* and other expeditions had taught us that closing mechanisms operating at great depths were uncertain pieces of machinery at best, and quite useless for gathering an adequate representation of the abyssal fauna. The necessity of long horizontal hauls has completely precluded their use.

Two phases of the Bermuda Oceanographic Expedition hauls, seldom if ever duplicated by other expeditions, are exceptionally interesting. The first of these is the accomplishment of hundreds of hauls at various levels in one location and over long periods of time, and the second is the long duration of each individual haul at its level compared with the time spent in going up and down. These two conditions make it relatively easy, with experience, to determine the life zones in the sea to which each organism belongs.

Complete time records of all of the nets used during the Bermuda Oceanographic Expeditions have been kept, and the following data show the percentage of time spent by a net at the desired depth compared with the total time the net was in the water:

100-*fathom nets*: These nets towed at this depth from 86% to 96% of their total towing time, their average effectiveness being 91.4%.

500-*fathom nets*: The nets towed at this depth from 70% to 83% of their total towing time, their average effectiveness being 79.4%.

1,000-*fathom nets*: The nets towed at this depth from 59% to 72% of their total towing time, their average effectiveness being 64.4%.

The exact determinations of the life zones of animals of the Bermuda deep-sea fauna, have been restricted, so far, to fishes. These are now being studied in the cases of the larger invertebrates and plankton.

CONTENTS OF A TYPICAL NET HAUL.

Net 779, Michael Sars metre net; Vessel, Tug *Gladisfen;* Date, July 5, 1930; Location, 5 m. SE to 15 m. SExS¾S of Nonsuch Island, Bermuda; Weather, overcast in A.M., rain squalls, clearing in P.M.; Wind, SW, 2 to 3; Sea, considerable swell, diminishing in P.M.; Time, beginning of haul 9:04 A.M., ending of haul 2:25 P.M., duration of haul, 5 hours, 21 minutes; Depth of net, 800 fathoms; Length of cable, 2,925 metres; Angle of cable, 30°.

Contents of Net.

General Character: Mostly copepods, schizopods and sagitta.
Copepods, comprising a dozen or more species, mostly calanoids, with also
     Corycaeus, Oithona, etc.
Schizopods, chiefly small species of *Euphausia,* with a dozen others belonging to two or three genera.

Shrimps, one specimen near *Pandalus danae.*

Ostracods, a few of one or two species.

Amphipods, few and small, a dozen individuals of four or five species.

Sagitta, apparently two or three species.

Polychaetes, one *Tomopteris septentrionale.*

Siphonophores, *Diphys truncata.*

Sponges, fair number of spicules of various kinds.

Radiolaria, large numbers of portions of a hexagonal framework and a few small, conical specimens mostly incomplete; numbers of perforated spherical species and Astrophaeroidea.

Diatoms, almost entirely absent. One specimen of *Asteromphalus heptactis,* also one cell of *Melosira moniliformis* and a *Coscinodiscus.*

Tintinnoinea, one *Tintinnopsis cylindrica* and one *Parafavella* near *P. acuta.*

Foraminifera, few, comprising two or three species.

Dinoflagellates, absent.

Fish larvae, three present, one belonging to a deep-sea species, with very large lower jaw and black spots on sides.

Fish, adolescent and adult:

　　　6 *Lampanyctus warmingi,* 11 to 21 mm.
　　　3 *Myctophum benoiti,* 11, 12 mm.
　　　1 *Lampadena chavesi.*
　　　13 *Myctophum laternatum,* 12 mm.
　　　14 *Cyclothone signata.*
　　117 *Cyclothone microdon.*
　　　1 *Cyclothone pallida.*
　　　1 *Bregmaceros macclellandii,* 45 mm.
　　　2 *Omosudis lowi,* 11, 38 mm.
　　　1 *Stomias ferox,* 80 mm.
　　　1 *Lestidium intermedium,* 87 mm.

In the preliminary work of this report, represented by ZOOLOGICA, Volumes XXI, Number 4 to 8 inclusive, the labors of Mr. G. H. Wailes have been very great, for he has patiently sorted out the various elements of many typical plankton hauls made in the course of these expeditions, and thus rendered the various phyla available for study by specialists.

This has resulted in a real contribution to the distribution and relative abundance of marine life in the vicinity of Bermuda, but it is only a beginning, for of the fifteen hundred-odd hauls made, from 1929 to the present time, selections for the following reports have been made from only 44, or about 3%.

Samples of marine plankton collected by Dr. William Beebe off Bermuda have been submitted to me and form the subject of the present reports. Further reports will be issued as the material is identified and reported upon.

I wish to express my thanks to Dr. Beebe for the privilege of examining the material and to all those who have kindly identified specimens, among whom I would especially mention the following for their courtesy in identifying specimens in the groups on which they are acknowledged authorities: Mrs. Edith Berkeley and Mr. C. C. A. Monro (Polychaetes), Dr. McLean Fraser (Hydroids), Mr. Clarence R. Shoemaker (Amphipods), Dr. C. B. Wilson (Copepods) and Dr. W. M. Tattersall (Schizopods), also Dr. W. A. Clemens for library facilities at the Departure Bay Station of the Biological Board of Canada.

LOCALITY.

The samples numbered from 1 to 13 were obtained in 1930 from an area eight miles in diameter, situated about eight miles south of Nonsuch Island, the center of this area being in 32° 12′ N. Lat. and 64° 36′ W. Long.

Samples numbered from 14 to 24 were taken during the autumn of 1933 somewhat farther inshore.

TABLE I.

Data on hauls.

Sample No.	Net No.	Depth Fath.	Metres	Date 1930	Time of Haul	Duration of Haul	Type of Net
1	779	800	1463	5 July	9.04 A.M.	5 hrs. 21 min.	1 metre
2	870	100	183	11 Sept.	10.03 A.M.	2-27	" "
	876	100	183	12 Sept.	11.22 A.M.	3-00	" "
3	871	200	366	11 Sept.	10.03 A.M.	2-27	" "
	877	200	366	12 Sept.	11.22 A.M.	3-00	" "
4	872	300	549	11 Sept.	10.03 A.M.	2-27	" "
	878	300	549	12 Sept.	11.22 A.M.	3-00	" "
5	873	400	732	11 Sept.	10.03 A.M.	2-27	" "
	879	400	732	12 Sept.	11.22 A.M.	3-00	" "
6	874	500	914	11 Sept.	10.03 A.M.	2-27	" "
	880	500	914	12 Sept.	11.22 A.M.	3-00	" "
7	875	600	1097	11 Sept.	10.03 A.M.	2-27	" "
	881	600	1097	12 Sept.	11.22 A.M.	3-00	" "
8	891	700	1280	15 Sept.	9.20 A.M.	4-00	" "
	896	700	1280	16 Sept.	9.29 A.M.	4-26	" "
	902	700	1280	17 Sept.	9.10 A.M.	4-05	" "
9	892	800	1463	15 Sept.	9.20 A.M.	4-00	" "
	897	800	1463	16 Sept.	9.29 A.M.	4-26	" "
	903	800	1463	17 Sept.	9.10 A.M.	4-00	" "
10	868	900	1646	10 Sept.	9.38 A.M.	2-52	" "
	886	900	1646	13 Sept.	9.33 A.M.	4-27	" "
	887	900	1646	13 Sept.	9.33 A.M.	4-27	" "
11	858	1000	1829	6 Sept.	9.07 A.M.	4-23	" "
	864	1000	1829	8 Sept.	9.29 A.M.	4-01	" "
	869	1000	1829	10 Sept.	9.38 A.M.	2-52	" "
12	900	0	0	16 Sept.	8.00 A.M.	1-00	" "
13	976	0	0	12 Oct.	2.00 A.M.	2-00	" "

Surface Hauls 1933

14	1358	0	0	17 Sept.	7.35 P.M.	1-00	1 ft. Diatom
15	1370	0	0	24 Sept.	5.00 A.M.	0-30	½-Metre
16	1378	0	0	27 Sept.	4.45 A.M.	0-20	1 Metre
17	1382	0	0	27 Sept.	4.45 A.M.	0-20	1 Metre
18	1380	0	0	27 Sept.	5.25 A.M.	0-20	1 Metre
	1381	0	0	27 Sept.	5.45 A.M.	0-20	1 Metre
19	1408	0	0	11 Oct.	7.45 P.M.	0-20	1 Metre
20	1411	0	0	11 Oct.	7.45 P.M.	0-20	½-Metre Diatom
21	1439	0	0	28 Oct.	2.15 P.M.	0-20	1 Metre
	1441	0	0	28 Oct.	2.40 P.M.	0-20	1 Metre
	1443	0	0	28 Oct.	3.15 P.M.	0-15	1 Metre
22	1442	1.6	3	28 Oct.	2.40 P.M.	0-20	1 ft. Diatom
	1444	1.6	3	28 Oct.	3.15 P.M.	0-15	1 ft. Diatom
23	1446	0	0	2 Nov.	4.45 A.M.	1-15	1 Metre
	1448	0	0	2 Nov.	6.00 A.M.	1-15	1 Metre
	1449	0	0	2 Nov.	4.45 A.M.	1-15	½-Metre
	1450	0	0	2 Nov.	6.00 A.M.	1-15	½-Metre
24	1457	1.6	3	11 Nov.	3.35 P.M.	0-20	½-Metre

From Table I it will be seen that each sample represents the combined results of from one to four separate net hauls, a total of 44 hauls being included out of more than fifteen hundred made by Dr. Beebe up to the present time.

General Composition of the Plankton.

Previous to the samples being received, in fact on the day of their collection, the larger organisms such as fish, large crustaceans and medusae, had been removed. The following remarks apply, therefore, to the remainder.

Deep-water Hauls: These, comprising Samples 1 to 11, were large, each consisting of from 400 to 500 cubic centimetres of organisms. All had mixed with them considerable quantities of long hairs and gelatinous material of unrecognized origin, much entangled with chaetognaths and crustaceans.

All the samples were of a similar general character and consisted of approximately 80% Crustacea, 10% Chaetognatha, 5% Coelenterata and 5% of various other organisms and débris.

The crustacean portions were composed on an average of about (by bulk) 40% schizopods, 35% shrimps and larvae, and 20-25% copepods, with a small mixture of amphipods, ostracods, isopods, crab zoea and other decapod larvae amounting to 1% or 2%.

Shallow-water Hauls: These were small in amount, varying from about 5 to 20 cubic centimetres each. The surface tows (Samples 12 and 13, Nets 900 and 976) were also small as they consisted only of portions of the hauls.

The surface hauls as represented by Samples 14 to 24 show great variation in the relative proportions of the various groups composing them, as can be seen from Table II.

Table II.

Estimated percentages (by bulk) of the organisms comprising samples 14 to 24. (Those present but not equal to 1% are indicated by "x").

Time	Pre-daylight Hauls, 4:45 to 6:00 A.M.						Daylight Hauls, 2:15 to 3:35 P.M.			Post-daylight Hauls, 7 to 8:00 P.M.	
Sample No............	15	16	17	18	19	23	21	22	24	14	20
Copepoda..............	87	25	38	5	25	82	2	3	25	15	22
Shrimps and Larvae....	10	72	50	60	37	10	92	96	68	70	2
Crab Zoea............	2	2	10	2	2	1	2	1	2	x	1
Squilla Larvae.........	—	—	—	x	—	—	1	—	1	—	—
Amphipoda...........	—	x	1	30	1	1	—	—	—	x	—
Isopoda..............	1	—	—	1	x	1	—	—	—	—	—
Ostracoda............	x	x	x	x	x	x	x	x	x	x	x
Polychaeta............	x	—	—	—	x	—	x	—	—	10	—
Chaetognatha.........	x	—	1	2	30	1	—	—	2	5	70
Siphonophora.........	—	—	—	—	3	3	1	—	1	—	5
Medusae..............	—	—	x	—	1	1	x	x	—	—	x
Tintinnoinea..........	x	x	—	—	—	—	—	—	—	x	—
Debris, etc...........	—	1	—	—	1	x	2	—	1	—	x

These differences occur even in the case of hauls taken simultaneously, as were Nos. 16 and 17, and are still more accentuated in No. 18 which was taken immediately afterward. This latter sample was the only one in which amphipods were present in larger quantities than 1%. In this instance the species *Synopia ultramarina* formed 30% of the catch.

General Results.

Nearly all of the identifications are new records for this region and extend the known distributions more or less considerably.

Aside from the pelagic organisms which are generally distributed in the oceans, the collection consists largely of species previously recorded from the tropical and eastern Atlantic and the Mediterranean areas.

An unexpected result of the examination of the material was the almost complete absence of diatoms and dinoflagellates. This may be due to Bermuda being situated in the Sargasso sea area where certain types of plankton are less plentiful than elsewhere.

5.

Plankton of the Bermuda Oceanographic Expeditions. II. Notes on Protozoa[1].

G. H. WAILES.

City Museum, Vancouver, B. C.

(Plates I & II).

This is one of a number of papers dealing with the planktonic contents of a selected series of nets drawn at various levels off the coast of Bermuda on the Bermuda Oceanographic Expeditions of the New York Zoological Society under the direction of Dr. William Beebe. Full details of the nets, locality, etc., will be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3, and Volume XXI, Numbers 3 and 4.

The following 39 species of Protozoa were taken in these nets:

PHYLUM PROTOZOA.

Subphylum Mastigophora.

Class Phytomastigoda.

Order Chrysomanadida.

Family Silicoflagellidae.
Dictyocha fibula (Ehrenberg). Rare.

Order Dinoflagellida. (Dinoflagellates).

Suborder Diniferina.

Family Noctilucidae.
Noctiluca scintillans (McCartney). Rare.

Family Peridinidae.
Goniodoma polyhedricum (Pouchet).
Gonyaulax digitale (Pouchet).
Peridiniopsis asymmetrica Mangin.
Peridinium cerasus Paulsen.
Peridinium claudicans Paulsen.
Peridinium conicum (Gran).
Peridinium grani Ostenfeld.
Peridinium oblongum (Aurivillius).
Ceratium fusus (Ehrenberg).
Ceratium trichocerus (Ehrenberg).
Ceratium tripos var. *atlantica* Ostenfeld.
Ceratium karsteni Pavillard.

Suborder Adinina.

Family Prorocentridae.

Prorocentrum micans Ehrenberg.

The dinoflagellates live in the upper layers of the ocean; most of the species recorded above were captured in surface hauls (Nets 1471, 1472, 1475 and 1476). They are all generally distributed in the North Atlantic ocean, none being purely tropical species.

Subphylum Sarcodina.

Class Actinopoda.

Subclass Radiolaria.

The Radiolaria occurred very sparsely in the deep-water hauls and the majority of individuals were mutilated or fragmentary. Probably nearly twenty species are represented. The material awaits further study.

Subphylum Infusoria.

Class Ciliata.

Order Heterotricha.

Suborder Tintinnoinea.

Examination of Haul 779 made in 800 fathoms and upward, 8 miles south of Bermuda, on July 5, 1930, afforded the following list of 22 species, of Tintinnids, except *Tintinnopsis bermudensis.*

No species occurred numerously and all (except *Parundella major*) have been recorded previously from either the tropical Atlantic, including the Sargasso sea, North Atlantic or Mediterranean sea.

Parundella major was first described in 1925 from the Strait of Georgia, British Columbia, and has also been recorded off San Francisco.

Tintinnopsis bermudensis occurred fairly numerously and was the only species observed in Surface Hauls 1355 and 1370 taken on Sept. 17 and 24, 1933 (close to the shore of Bermuda over depths of five fathoms or less). In 16 similar hauls taken from Sept. 27 to Nov. 11, 1933, no species of tintinnid was seen.

In the accompanying plates figures are given of the species as here recorded.

An examination of 24 hauls made during September, 1930, at depths from 100 fathoms to 1,000 fathoms, 8 miles off Bermuda, disclosed no tintinnids as present. Neither were any present in two surface hauls made at the same time and place.

For information on the synonymy and distribution of the species, the conspectus of this suborder by Kofoid and Campbell (University of California Press, Vol. 34, pp. 1-403, 697 Figs. in text, 1929) should be consulted.

Family Codonellidae Kofoid and Campbell.

Tintinnopsis Stein emended.

T. *bermudensis* Brandt. (Fig. 1).

T. *cylindrica* Daday. (Fig. 2). Generally distributed.

T. *major* Meunier. North Atlantic.

Codonella Haeckel emended.

C. *amphorella* Biedermann. (Fig. 5).

C. *angusta* Kofoid and Campbell. Sargasso sea.

C. *apicata* Kofoid and Campbell (Fig. 4).

C. *nationalis* Brandt. (Fig. 7). Atlantic ocean.

    C. oceanica Brandt emended. (Fig. 8). Gulf Stream.
    C. rapa Kofoid and Campbell. (Fig. 6).
    C. recta Kofoid and Campbell. Agulhas Current.

Family Codonellopsidae Kofoid and Campbell.
    Stenosemella Jörgensen.
        S. ventricosa (Claparède and Lachmann). (Fig. 3).
    Codonellopsis Jörgensen.
        C. longa Kofoid and Campbell. (Fig. 17).
        C. tessellata (Brandt). (Fig. 16). Sargasso sea.

Family Cyttarocylidae Kofoid and Campbell.
    Cyttarocylis Fol emended.
        C. magna Brandt. (Fig. 15).
        C. plagiostoma (Daday). (Fig. 18). Atlantic ocean.

Family Ptychocylidae Kofoid and Campbell.
    Epiplocylis Jörgensen.
        E. sargassensis (Brandt) emended. (Fig. 9).

Family Xystonellidae Kofoid and Campbell.
    Parundella Jörgensen emended.
        P. major Wailes. (Fig. 20). Off west coast of North America.

Family Undellidae Kofoid and Campbell.
    Proplectella Kofoid and Campbell.
        P. acuta Jörgensen. (Fig. 11). Mediterranean sea.
        P. claparèdei (Entz Sr.). (Fig. 10).

Family Dictyocystidae Haeckel emended.
    Dictyocysta Ehrenberg emended.
        D. dilatata Brandt. (Figs. 12, 13). Sargasso sea.
        D. lata Kofoid and Campbell. (Fig. 14). Sargasso sea.

Family Tintinnidae Claparède and Lachmann emended.
    Tintinnus Schrank emended.
        T. macilentus Jörgensen emended. (Fig. 19). North Atlantic,
        New Zealand.

Order Peritrichida.
    Family Vorticellidae.
        Cothurnia imberbis Ehrenberg.

Class Suctoria.
    Family Acinetidae.
        Acineta tuberosa Ehrenberg

    The last two species were attached to floating alga. They are littoral forms and generally distributed.

EXPLANATION OF THE PLATES.

Note: All Figures magnified 375 times.

PLATE I.

Fig. 1. *Tintinnopsis bermudensis* Brandt. Total length 84-94μ, greatest diameter 60-68μ, diameter of collar 45μ.

Fig. 2. *Tintinnopsis cylindrica* Daday. Diameter 38-40μ, length 140-150μ.

Fig. 3. *Stenosemella ventricosa* (Claparède & Lachmann). Length 68-83μ, diameter 55-68μ.

Fig. 4. *Codonella apicata* Kofoid & Campbell. Length 75μ, greatest diameter 59μ, diameter of collar 42μ, height of collar 16μ.

Fig. 5. *Codonella amphorella* Biedermann. Length 89-98μ, greatest diameter 55μ, length of horn, 18-26μ, length of collar 22-23μ, diameter of neck 36-40μ.

Fig. 6. *Codonella rapa* Kofoid & Campbell. Length 90-96μ, greatest diameter 49-50μ, length of horn 20μ, length of collar 23μ.

Fig. 7. *Codonella nationalis* Brandt. Length 74-84μ, greatest diameter 55-64μ, length of collar 19-20μ.

Fig. 8. *Codonella oceanica* Brandt emended. Length 84μ, greatest diameter 66μ.

Fig. 9. *Epiplocylis sargassensis* Brandt emended. Length 132μ, greatest diameter 70μ.

Fig. 10. *Proplectella claparèdei* (Entz Sr.). Length 58-65μ, greatest diameter 40-42μ, aperture 36μ.

Fig. 11. *Proplectella acuta* Jörgensen. Length 68μ, diameter 39μ, aperture 33μ.

Figs. 12, 13. *Dictyocysta dilatata* Brandt. Length 61-65μ, diameter 40-45μ, diameter of collar 34-39μ, height of collar 16μ.

Fig. 14. *Dictyocysta lata* Kofoid & Campbell. Length 65μ, diameter of bowl 53μ, diameter of collar 50μ, height of collar 30μ.

PLATE II.

Fig. 15. *Cyttarocylis magna* Brandt. Length 268μ, greatest diameter 130μ.

Fig. 16. *Codonellopsis tessalata* (Brandt). Length of bowl and neck 80μ, diameter of bowl 68-70μ, diameter of neck 42-52μ, length of horn 32-42μ, total length up to about 225μ.

Fig. 17. *Codonellopsis longa* Kofoid & Campbell. Total length 235μ, greatest diameter of bowl 65μ.

Fig. 18. *Cyttarocylis plagiostoma* (Daday). Length 106-123μ, diameter of aperture 105-117μ.

Fig. 19. *Tintinnus macilentus* Jörgensen emended. Length 160μ, oral aperture 38μ diameter, aboral aperture 24μ diameter.

Fig. 20. *Parundella major* Wailes. Diameter 30-32μ, length 130-136μ.

PLATE I.

NOTES ON PROTOZOA.

15

16

17

18

19

20

NOTES ON PROTOZOA.
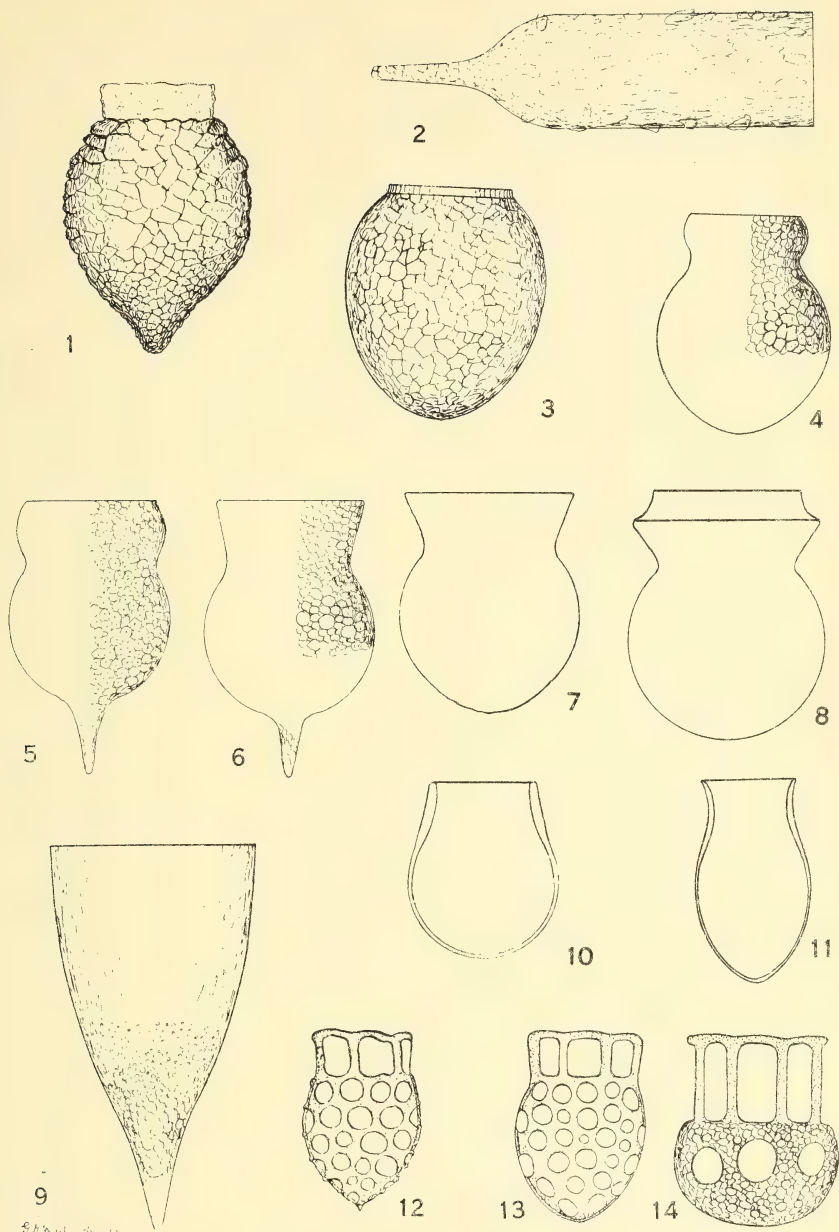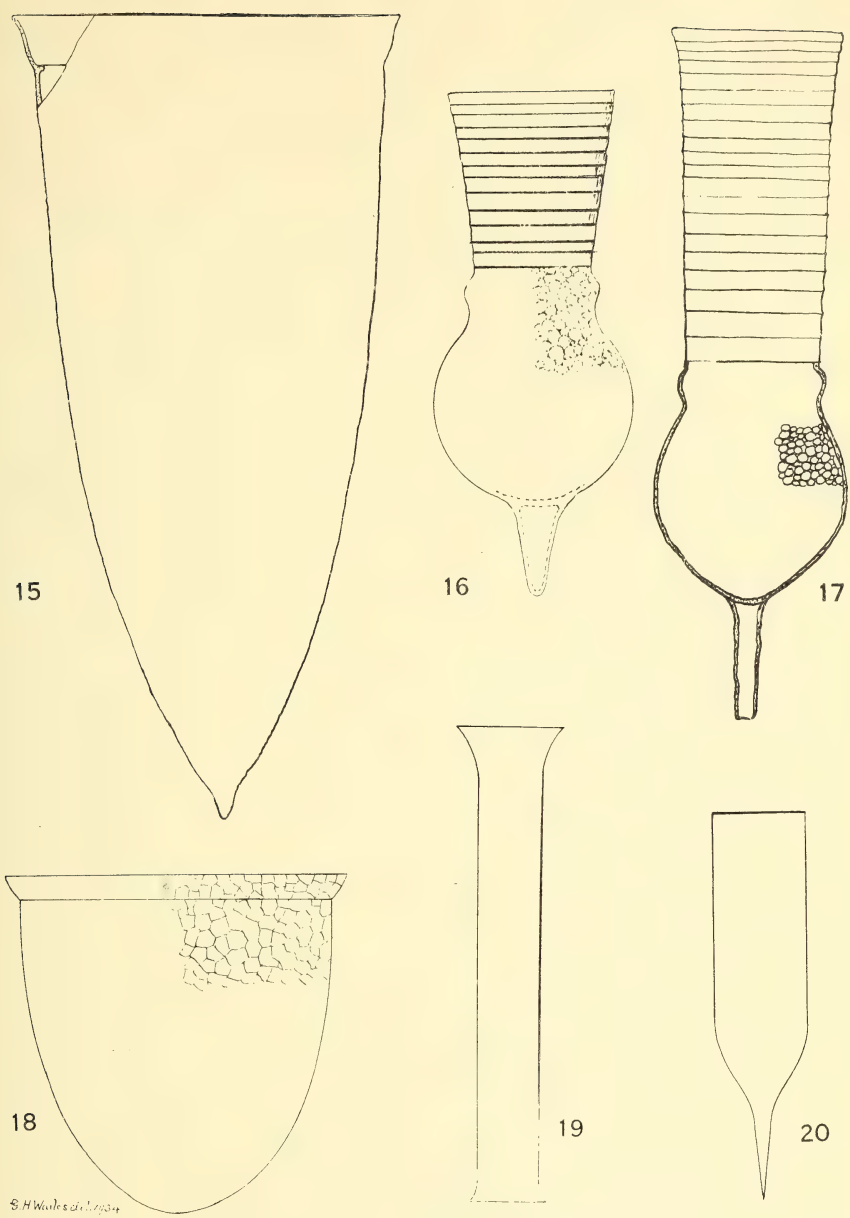
6.

Plankton of the Bermuda Oceanographic Expeditions. III. Notes on Polychaeta[1].

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This is one of a number of papers dealing with the planktonic contents of a selected series of nets drawn at various levels off the coast of Bermuda on the Bermuda Oceanographic Expeditions of the New York Zoological Society under the direction of Dr. William Beebe. Full details of the nets, locality, etc., will be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3, and Volume XXI, Numbers 3 and 4.

The identifications in the following list were made from specimens submitted to me by G. H. Wailes.

Certain members of Syllidae and Nereidae have pelagic swarming forms, which accounts for their capture in the plankton. This is also true of the members of the family Opheliidae included in the following list. The members of the genera *Lopadorhynchus, Vanadis, Alciopa, Corynocephalus, Travisiopis,* and *Tomopteris* are true pelagic forms. The genus *Nectochaeta* is bathypelagic.

All the species here enumerated are generally distributed in the Atlantic ocean.

PHYLUM ANNELIDA.

Class Chaetopoda.

Order Polychaeta.

Family Phyllodocidae Grube.
Lopadorhynchus Grube.
L. nationalis Reibisch.
L. uncinatus Fauvel.

Family Alciopidae Ehlers.
Vanadis Claparède.
V. longissima (?) (Levinsen).
V. formosa Claparède.
Alciopa Audouin et M. Edwards.
A. cantraini (Della Chiaje).
Corynocephalus Levinsen.
C. albo-maculatus Levinsen.

Family Typhloscolecidae Uljanin.
Travisiopsis Levinsen.
T. lobifera Levinsen.

Family Tomopteridae Grube.
   Tomopteris Eschscholtz.
      T. apsteini Rosa.
      T. nisseni Rosa.

Family Opheliidae Grube.
   Polyophthalmus Quatrefages.
      P. pictus (Dujardin).
   Armandia Filippi.
      A. polyophthalmia Kükenthal.

Family Leodicidae Treadwell.
   Nematonereis Schmarda.
      N. unicornis (?) (Grube). A very small
         incomplete specimen.

Family Syllidae Grube.
   Grubea Quatrefages.
      G. clavata Claparède.

Family Polynoidae.
   Nectochaeta Marenzeller.
      N. caroli Fauvel.

From a portion of the material the following additional species were identified by C. C. A. Monro (British Museum).

Family Nereidae Quatrefages.
   Nereis Cuvier.
      N. riisei Grube. Surface (Net 900).
   Ceratonereis Kinberg.
      C. mirabilis Kinberg. Surface (Net
         900, September to November).
   Perinereis Kinberg.
      P. bairdii Webster. Surface (September
         to November).
      P. sp. Surface (Net 900).

Family Glyceridae Grube.
   Glycera Savigny.
      G. tesselata Grube. Surface.

Family Polynoidae Kinberg.
   Nectochaeta Marenzeller.
      N. grimaldii Marenzeller. 1,000 fathoms and up.
   Harmothoe Kinberg.
      H. benthophila Ehlers. 1,000 fathoms and up.

Family Spionidae Sars.
   Chaetosphaera Haecker.
      C. sp. Haecker. September to October. Surface (Net
         1370). Post-larvae.

Mr. Monro writes that all the forms in the above list identified by him are epitocons, sexually modified forms, except the polynoids *Nectochaeta grimaldii* and *Harmothoe benthophila,* which probably represent a phase in the life of some well known benthic species. *Chaetosphaera* is a post-larva of which the adult is not known.

Selected Literature.

Apstein, C., Die Alciopiden und Tomopteriden der Plankton-Expedition. (Kiel). 1900.

Reibisch, J., Die Pelagischen Phyllodicen und Typhloscoleciden der Plankton-Expedition, Vol. 2. (Kiel). 1895.

Fauvel, P., Faune de France, Vol. 5 (Polychètes errantes), 1923, and Vol. 16 (Polychètes sédentaires), 1927.

7.

Plankton of the Bermuda Oceanographic Expeditions.
IV. Notes on Copepoda[1].

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This is one of a number of papers dealing with the planktonic contents of a selected series of nets drawn at various levels off the coast of Bermuda on the Bermuda Oceanographic Expeditions of the New York Zoological Society under the direction of Dr. William Beebe. Full details of the nets, locality, etc., will be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3, and Volume XXI, Numbers 3 and 4.

The deep-water hauls provided large collections of copepods. From these, 11 vials of specimens selected by G. H. Wailes were examined by me and yielded 101 species; other identifications brought the number of species now recorded to a total of 112.

Of this number I have recorded 44 species (40%) from the Woods Hole Region (U. S. Nat. Mus., Bull. 158, 1932) and all have previously been recorded from the Atlantic or Mediterranean areas.

The genus *Copilia* was represented by one or two individuals in nearly every haul and specimens of the genus *Sapphirina* also occurred in several. The genus *Corycaeus* was represented more or less numerously in all hauls.

One individual each of *Gaetanus caudani* and of *Gaetanus latifrons* were obtained in Sample 9 (800 fathoms).

The surface hauls were characterized by the predominance of *Acartia clausi* and *Paracalanus parvus;* other species noted in them were *Corycaeus* spp., numerously, and *Oncaea* spp., sparsely, also *Mecynocera clausi, Clausocalanus arcuicornis, Euchaeta acuta, Candacia aethiopica, Candacia simplex, Pontellina plumata, Calanopia elliptica, Macrosetella gracilis, Miracia efferata, Oithona spinirostris, Lubbockia squillimana, Sapphirina angusta, Sapphirina auronitens, Sapphirina metallina* and a number of calanoids not specifically identified.

A single specimen of *Caligus curtus* was observed in Sample 18.

Order Copepoda.

    Suborder Calanoida.

        Family Calanidae.

            Genus *Calanus* Leach 1819.

                C. propinquus Brady.

            Genus *Megacalanus* Wolfenden 1904.

                M. longicornis Sars.

                M. princeps (Brady) Sars.

                M. sp. (immature).

Genus *Neocalanus* Sars 1925.
    *N. *gracilis* (Dana) Sars.
    N. *robustior* (Giesbrecht) Sars.
Genus *Undinula* A. Scott 1909.
    U. *darwini* (Lubbock) Scott.
    *U. *vulgaris* (Dana) Scott.
Genus *Eucalanus* Dana 1852.
    *E. *attenuatus* (Dana).
    E. *crassus* Giesbrecht.
    *E. *elongatus* (Dana).
    E. *mucronatus* Giesbrecht.
    E. *pileatus* Giesbrecht.
    E. *subtenuis* Giesbrecht.
Genus *Rhincalanus* Dana 1852.
    *R. *cornutus* Dana.
    *R. *nasutus* Giesbrecht.
Genus *Mecynocera* I. C. Thompson 1888.
    *M. *clausi* I. C. Thompson.
Genus *Bathycalanus* G. O. Sars 1905.
    B. *richiardi* G. O. Sars.
    B. *rigidus* G. O. Sars.

Family Paracalanidae.
Genus *Paracalanus* Boeck 1865.
    *P. *parvus* (Claus) Sars.
Genus *Calocalanus* Giesbrecht 1888.
    *C. *pavo* (Dana) Giesbrecht.

Family Pseudocalanidae.
Genus *Clausocalanus* Giesbrecht 1888.
    *C. *arcuicornis* (Dana).
Genus *Pseudocalanus* Boeck 1872.
    *P. *minutus* (Krøyer).

Family Aetideidae.
Genus *Aetideus* Brady 1883.
    *A. *armatus* (Boeck).
Genus *Chiridius* Giesbrecht 1892.
    C. *poppei* Giesbrecht.
Genus *Chirundina* Giesbrecht 1895.
    *C. *streetsii* Giesbrecht.
Genus *Gaetanus* Giesbrecht 1888.
    G. *armiger* Giesbrecht.
    G. *caudani* Canu.
    G. *latifrons* G. O. Sars.
    *G. *miles* Giesbrecht.
Genus *Gaidius* Giesbrecht 1895.
    *G. *brevispinus* (G. O. Sars).
    *G. *tenuispinus* (G. O. Sars).
Genus *Mesogaidius* Wolfenden.
    M. *intermedius* Wolfenden.
Genus *Euchirella* Giesbrecht 1888.
    E. *brevis* (G. O. Sars).
Genus *Undeuchaeta* Giesbrecht 1888.
    *U. *major* Giesbrecht.
    U. *spectabilis* (G. O. Sars).

Genus *Pseudochirella* G. O. Sars 1920.
    P. obesa G. O. Sars.
    P. obtusa (G. O. Sars).
    P. pustilifera (G. O. Sars).
Genus *Pseudaetideus* Wolfenden 1904.
    P. armatus (Boeck).

Family Euchaetidae.
    Genus *Euchaeta* Philippi 1843.
        E. acuta Giesbrecht.
        *E. marina (Prestandrea) Giesbrecht.
    Genus *Paraeuchaeta* A. Scott 1909.
        P. bisinuata (G. O. Sars).
        P. hanseni (With.).
    Genus *Pseudeuchaeta*.
        P. norvegica (Boeck).

Family Phaennidae.
    Genus *Phaenna* Claus 1863.
        P. spinifera Claus.

Family Scolecithricidae.
    Genus *Scottocalanus* G. O. Sars 1905.
        S. securifrons (T. Scott).
    Genus *Scolecithrix* Brady 1883.
        S. bradyi Giesbrecht.
        *S. danae (Lubbock) Giesbrecht.
    Genus *Scolecithricella* G. O. Sars 1902.
        S. abyssalis (Giesbrecht).

Family Centropagidae.
    Genus *Centropages* Krøyer 1849.
        C. violaceus (Claus).

Family Metridiidae.
    Genus *Metridia* Boeck 1864.
        *M. brevicauda Giesbrecht.
        *M. longa (Lubbock).
        *M. lucens Boeck.
        M. normani Giesbrecht.
        *M. princeps Giesbrecht.
        M. venusta Giesbrecht.
    Genus *Pleuromamma* Giesbrecht 1898.
        *P. abdominalis (Lubbock) Gies. & Schmeil.
        *P. gracilis (Claus) Giesbrecht.
        P. quadrungulata (F. Dahl).
        *P. robusta (F. Dahl) Sars.
        *P. xiphias (Giesbrecht).

Family Lucicutiidae.
    Genus *Lucicutia* Giesbrecht 1898.
        L. clausi (Giesbrecht).
        L. flavicornis (Claus).
        L. longicornis Giesbrecht.
        *L. magna Wolfenden.
        L. maxima Steuer.

Family   Heterorhabdidae.
  Genus *Heterorhabdus* Giesbrecht 1898.
      H. grimaldi (Richard).
     *H. *longicornis* (Giesbrecht).
      H. papillager (Claus).
      H. spinifrons (Claus).
  Genus *Haloptilus* Giesbrecht 1898.
      H. ornatus (Giesbrecht).
      H. longicornis (Claus).
  Genus *Euaugaptilus* G. O. Sars 1920.
      E. elongatus (G. O. Sars).

Family   Candaciidae.
  Genus *Candacia* Dana 1846.
      C. simplex (Giesbrecht).
      C. aethiopica (Dana).

Family   Pontellidae.
  Genus *Pontellina* Dana 1853.
     *P. *plumata* (Dana).
  Genus *Calanopia* Dana 1852.
      C. elliptica (Dana).

Family   Acartiidae.
  Genus *Acartia* Dana 1846.
     *A. *clausi* Giesbrecht.
     *A. *danae* Giesbrecht.

Suborder Harpacticoida.

Family   Ectinosomidae.
  Genus *Microsetella* Brady & Robertson 1873.
     *M. *norvegica* (Boeck).

Family   Macrosetellidae.
  Genus *Macrosetella* A. Scott 1909.
      M. gracilis (Dana).
  Genus *Miracia* Dana 1846.
     *M. *efferata* Dana.

Family   Tachidiidae.
  Genus *Clytemnestra* Dana 1847.
      C. scutellata Dana.

Suborder Cyclopoida.

Family   Oithonidae.
  Genus *Oithona* Baird 1843.
      O. attenuata Farran.
     *O. *similis* Claus.
     *O. *spinirostris* Claus.

Family   Oncaeidae.
  Genus *Oncaea* Philippi 1843.
      O. conifera Giesbrecht.
      O. curta G. O. Sars.
      O. media Giesbrecht.
      O. mediterranea Claus.

        *O. *minuta* Giesbrecht.
        O. *tenella* G. O. Sars.
        *O. *venusta* Philippi.
  Genus *Conaea* Giesbrecht 1891.
        C. *rapax* Giesbrecht.
  Genus *Lubbockia* Claus 1863.
        L. *aculeata* Giesbrecht.
        L. *squillimana* Claus.

Family Corycaeidae.
  Genus *Corycaeus* Dana 1845.
        C. *agilis* Dana.
        C. *carinatus* Giesbrecht.
        C. *catus* M. Dahl.
        C. *crassiusculus* Dana.
        *C. *elongatus* Claus.
        C. *lautus* Dana.
        C. *limbatus* Brady.
        *C. *speciosus* Dana.
        C. *typicus* Krøyer.
  Genus *Farranula* Blake 1932.
        F. *carinata* (Giesbrecht).
  Genus *Sapphirina* J. V. Thompson 1829.
        *S. *angusta* Dana.
        *S. *auronitens* Claus.
        S. *metallina* Dana.
  Genus *Copilia* Dana 1849.
        C. *quadrata* Dana.
        C. *vitrea* Haeckel.

Suborder Caligoida.

Family Caligidae.
  Genus *Caligus* Müller 1785.
        *C. *curtus* Müller.

Note: The species marked "*" have been recorded from the Woods Hole region by Wilson.

8.

Plankton of the Bermuda Oceanographic Expeditions. V. Notes on Schizopoda[1].

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This is one of a number of papers dealing with the planktonic contents of a selected series of nets drawn at various levels off the coast of Bermuda on the Bermuda Oceanographic Expeditions of the New York Zoological Society under the direction of Dr. William Beebe. Full details of the nets, locality, etc., will be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3, and Volume XXI, Numbers 3 and 4.

All of the species of schizopods here recorded are well known in the North Atlantic and have been reported previously either by Hansen or Tattersall from the eastern coast of North America. The only species which is new to this area is the mysid *Longithorax* sp. nov.

PHYLUM ARTHROPODA.

Class Crustacea.

Order Euphausiacea.

Bentheuphausia amblyops Sars. 1,000-500 fathoms. Few.
Thysanopoda tricuspidata Milne-Edwards. 700 fathoms. One.
Thysanopoda aequalis Hansen. 1,000-300 fathoms. Very numerous.
Thysanopoda obtusifrons Sars. 1,000, 900, 400 fathoms. Few.
Euphausia brevis Hansen. 1,000-300 fathoms, mostly at 500 fathoms. Numerous.
Euphausia mutica Hansen. 500 fathoms. Rare.
Euphausia americana Hansen. 900-300 fathoms. Few.
Euphausia tenera Hansen. 1,000-500 fathoms. Few.
Euphausia hemigibba Hansen. 1,000-300 fathoms. Numerous in 500 fathoms.
Euphausia gibboides Ortmann. 200 fathoms. One.
Thysanoëssa parva Hansen. 1,000-400 fathoms. Numerous.
Nematoscelis tenella Sars. 900-200 fathoms. Few.
Nematoscelis microps Sars. 1,000-200 fathoms. Numerous.
Stylocheiron carinatum Sars. 500 fathoms. Four seen.
Stylocheiron suhmi Sars. 200 fathoms. One.
Stylocheiron longicorne Sars. 900-300 fathoms. Numerous.
Stylocheiron abbreviatum Sars. 900, 800, 400 fathoms. One in each haul.
Stylocheiron elongatum Sars. 1,000-200 fathoms. Numerous.

Order Mysidacea.

Anchialina typica (Krøyer). Surface, Net 900. One.
Euchaetomera tenuis Sars. 400 fathoms. One
Longithorax sp. nov. Surface, Net 900. Fourteen. Surface, Net 976.
    Six. 400 fathoms, one; 500 fathoms, one.

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    1915.

Tattersall, W. M., Crustaceans of the Orders Euphausiacea and Mysi-
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    Art. 8, pp. 1-31, Pls. 1, 2. 1926.

9.

Plankton of the Bermuda Oceanographic Expeditions. VI. Bathypelagic Nemerteans Taken in the Years 1929, 1930 and 1931[1].

Wesley R. Coe.

Osborn Zoological Laboratory, Yale University.

(Plates I-X; Text-figure 1).

The Bermuda Oceanographic Expeditions, under the direction of Dr. William Beebe, were organized for the purpose of making an intensive faunal survey of a closely limited area of the deep subtropical ocean. The area chosen was a circle eight miles in diameter, with its center located at 32° 12′ N. Lat., 64° 36′ W. Long., a point about nine miles southeast of Nonsuch Island, Bermuda. (Text-fig. 1). The depth at this locality is 1,000 to more than 1,400 fathoms, but most of the nets were so arranged as to collect samples simultaneously at 100-fathom intervals from 500 to 1,000

[1] Contribution No. 500, Department of Tropical Research, New York Zoological Society.
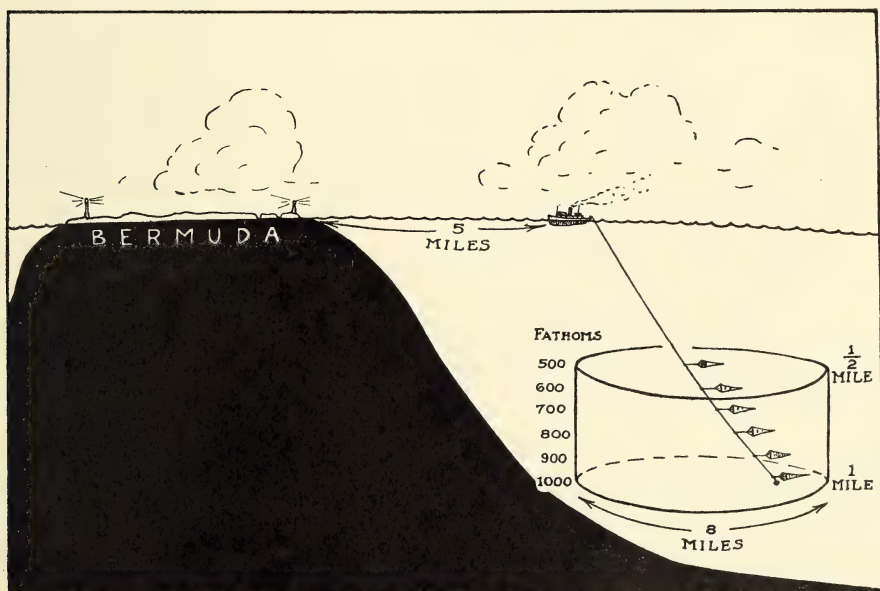
Text-figure 1.

Diagram showing location of Beebe eight-mile cylindrical trawling area and the arrangement of collecting nets in which the bathypelagic nemerteans of this report were obtained. (From Beebe).

fathoms inclusive. During the three summers, 1929 to 1931, a total of 1,042 nets one metre in diameter were drawn at these depths in all directions across this imaginary cylinder of water.

From the enormous volume of water which passed through these nets a total of 79 specimens of bathypelagic nemerteans was obtained. These represented 12 species, belonging to 10 genera, of which 6 species proved to be new to science. Many of the others are of great interest, not only because of the information which they furnish as to the geographical range of little-known species but more particularly because their study has supplemented our knowledge of the morphological peculiarities of several species of which only one or two individuals, representing only one of the sexes, had been previously recorded. No representatives of the group have been previously reported from this region. One species, *Pachynemertes obesa*, was a member of a new genus.

A list of the species secured by the expeditions, together with the number of specimens and the depth at which they were obtained, is as follows:

Species	Depth	No. Specimens
1. *Protopelagonemertes hubrechti* Brink.	1,400-1,800 m.	3
2. *Protopelagonemertes beebei* sp. nov.	1,646 m.	1
3. *Plotonemertes adhaerens* Brink.	1,300-1,830 m.	27
4. *Plotonemertes aurantiaca* sp. nov.	1,463 m.	1
5. *Crassonemertes robusta* Brink.	1,100 m.	2
6. *Pachynemertes obesa* gen. nov.; sp. nov.	1,646 m.	1
7. *Paradinonemertes wheeleri* sp. nov.	1,300-1,830 m.	6
8. *Planonemertes labiata* sp. nov.	1,800 m.	2
9. *Phallonemertes murrayi* Brink.	1,500-1,830 m.	2
10. *Chuniella lanceolata* Brink.	1,646 m.	1
11. *Nectonemertes mirabilis* Verrill.	1,300-1,830 m.	32
12. *Balaenanemertes minor* sp. nov.	549 m.	1

Total 79

When it is realized that a total of only about fifty species of these bathypelagic nemerteans has previously been described from all the oceans of the world it is surprising to find so many as here recorded for a single locality. Only 6 of the 12 species were previously known to science and in only 2 of these, *Phallonemertes murrayi* and *Nectonemertes mirabilis*, were both sexes known.

The fact that in several cases only a single specimen of the species was obtained in a total of 600 to 800 nets lowered to the water layer which the species inhabits and drawn there horizontally for upwards of four hours indicates how exceedingly sparse the population must be, for the worms are so sluggish that they could not escape capture if the nets reached their exact position. This makes it seem probable that even this cylindrical mass of water, in spite of such intensive exploration, may still harbor additional species.

It has been found that water layers of similar physical and chemical characteristics extend for great distances in the oceans at depths of 1,000 metres or more. Consequently the bathypelagic species, even though they be limited to a particular water layer, may have a wide geographical distribution. It is consequently not surprising to find in the Bermuda collections species hitherto recorded only from such remote seas as extend from southern Greenland to the coasts of Great Britain.

At the Beebe eight-mile circle the temperature of the water at 1,200 m. is about 5.29° C. and the salinity 35.08; at 1,600 m. to 2,500 m. the temperature varies only from 3.96° to 3.21° C., the salinity from 35.04 to 34.96, the density 27.81-27.89, the oxygen 5.9 to 6.0 per L., the pH 8.06-8.15 and

the PO$_4$ 45-48. Such stable conditions allow a great vertical range below 1,200 m. and an almost unlimited geographical range. But since the bathypelagic nemerteans are poorly adapted for active locomotion their rate of dispersal would be extremely slow were it not for the ocean currents which may carry them for very great distances.

With the exception of *Planonemertes*, which is known only from the Pacific ocean, all the genera represented in the collections have been previously reported for some portion of either the North or South Atlantic ocean. Curiously enough several genera, including *Dinonemertes Planktonemertes, Buergeriella, Amaueria* and *Natonemertes*, which are known to inhabit similar water layers in other parts of the North Atlantic, were not taken at the Bermuda area.

The bathymetrical distribution of the species collected at Bermuda is indicated in the following table (Table I).

TABLE I.

Bathymetrical Distribution of Bathypelagic Nemerteans Collected by 1,042 Nets Drawn Across the Beebe Eight-mile Cylindrical Trawling Area off Bermuda, Indicated by Number of Specimens Obtained at each Depth. (Depths at which these species have been previously obtained are indicated by "x." The figures representing temperature and salinity refer to the Bermuda area only).

Depth m.	Temp. °C.	Salinity.	Pr. hubrechti.	Pr. beebei.	Pl. adhaerens.	Pl. aurantiaca.	Cr. robusta.	Cr. obesa.	Pa. wheeleri.	Pl. labiata.	Ph. murrayi.	Ch. lanceolata.	N. mirabilis.	B. minor.
500	....	....	....	....	....	....	....	....	....	....	....	....	x	....
600	14.5	35.91	....	....	....	....	....	....	....	....	....	....	x	1
700	....	....	....	....	....	....	....	....	....	....	....	....	x	....
800	10.3	35.35	....	....	....	....	x	....	....	....	....	....	x	....
900	....	....	....	....	....	....	....	....	....	....	....	....	x	....
1,000	6.8	35.07	....	....	....	....	....	....	....	....	....	x	x2	....
1,100	....	....	....	....	....	....	1	....	....	....	....	....	x1	....
1,200	5.3	35.08	....	....	....	....	....	....	....	....	....	....	x2	....
1,300	....	....	x	....	2	....	1	....	1	....	....	....	x1	....
1,400	....	....	1	....	4	....	....	....	....	....	....	....	x2	....
1,500	....	....	....	....	6	1	....	....	....	....	1	....	x3	....
1,600	4.0	34.99	1	1	8	....	....	1	3	....	x	....	x5	....
1,700	....	....	....	....	3	....	x	....	....	....	x	1	x2	....
1,800	....	....	1	....	4	....	....	....	2	1	x1	....	x8	....
1,900	....	....	x	....	1	....	....	....	....	....	....	....	x6	....
2,000	3.5	35.04	x	....	x	....	....	....	....	....	x	x	x	....

KEY TO THE GENERA OF BATHYPELAGIC NEMERTEANS FROM THE BERMUDA AREA:

A. Body without tentacles in either sex..B
   B.   Mouth and proboscis opening united; body slender, narrowed at both ends; proboscis sheath nearly as long as body.
Protopelagonemertes

BB. Mouth more or less widely separated from proboscis opening.......C

C. Musculature of proboscis sheath of interlaced circular, spiral and longitudinal fibers..D

    D.   Body swollen and nearly cylindrical anteriorly, flattened and sharply recurved in posterior portion; with pair of specialized integumental glandular organs on ventral surface; proboscis very large..............................*Plotonemertes*

   DD. Body broad and more or less flattened; without specialized glandular organs ....E

      E.   Body broad, oval, thick; caudal fin narrow and sharply demarcated from body; mouth and proboscis opening not widely separated; intestinal diverticula much branched, with well developed ventral branch.
Crassonemertes

     EE. Body short, thick, rounded; caudal fin slightly differentiated; intestinal diverticula without ventral branches. ....*Pachynemertes*

    EEE. Body much flattened; caudal fin broad and not sharply demarcated from body; mouth and proboscis opening widely separated; intestinal diverticula with rudimentary ventral branch or none........................F

       F. Body rather narrow, with parallel lateral margins, much flattened posteriorly and continuing into flat caudal fin; mouth anterior to brain; spermaries of adult males with strong muscular walls and highly developed sperm ducts which continue beyond body as long, tubular penes.
Phallonemertes

      FF. Body oval and very flat; mouth on ventral surface of head, slightly anterior, beneath or slightly posterior to brain commissures, according to state of contraction of cephalic tissues; spermaries without external penes.....*Paradinonemertes*

CC. Circular and longitudinal muscles of proboscis sheath in separate layers ....G

    G.   Proboscis sheath composed of three more or less separate layers; body broad and very flat........................*Planonemertes*

   GG. Proboscis sheath of two layers, outer circular and inner longitudinal; body slender, rounded anteriorly, tapered to narrow posterior extremity..*Chuniella*

AA. Body with pair of lateral tentacles in one or both sexes; caudal fin highly developed ....H

    H.   Tentacles develop in adult males only; body slender.*Nectonemertes*

   HH. Tentacles in both sexes; body broad........................*Balaenanemertes*

Genus *Protopelagonemertes* Brinkmann.

1. *Protopelagonemertes hubrechti* Brinkmann.

Brinkmann, 1917, 1917a, page 178; Coe, 1926.

(*Bathynemertes hubrechti* Brinkmann, 1917, 1917a; Wheeler, 1934).

(Figs. 16, 18, 28, 29-31).

Two typical specimens of this species were contained in the Beebe collections. Both were females, as was also the type specimen. One of these measured 30 x 5 x 2 mm. and the other 40 x 5 x 2 mm. The type specimen

measured 56 mm. in length and 10 mm. in greatest width. The body is pointed at both ends and is much more slender and relatively thicker than in most bathypelagic forms. A third specimen, also female, was evidently a giant of the race, for its bulk exceeded by many times the largest of the other individuals. It measured after preservation 78 mm. in length, 22 mm. in width and about 10 mm. in thickness (Figs. 18, 28). Its massive appearance seemed to indicate a distinct species, but careful study of the internal anatomy showed a general conformity with other individuals except for the vastly greater size of the organ systems.

Color in life red, scarlet or orange.

Mouth and proboscis opening united into a common atrium which may disappear when proboscis is partially everted. Intestinal diverticula with both dorsal and ventral lobulated branches. Lateral nerve cords with single fibrous core.

The relatively large proboscis is provided with 27-29 well defined nerves through most of the length of the anterior chamber, although some of the sections in one specimen show only 26 and in another 30; posterior to the nerve ring in the middle chamber the number of distinct nerves is reduced from 29 to 13-18. Specimens from the South Atlantic, referred to this species by Wheeler, had only 22, 24, 25 or 26 proboscidial nerves. The basis is sharply curved and is provided with numerous sharply-pointed conical stylets (Figs. 41, 42). About twenty accessory stylets of similar form lie in six small pouches on the adjacent wall (Fig. 42). The proboscis sheath reaches three-fourths to seven-eighths the length of the body. The sheath is composed of closely interwoven fibers.

The female has thirty or more pairs of large, elongated ovaries, each containing many ova. Each gonad is crescentic in section, with its tip near the median line when fully mature and with an arch above the nerve cord leading to the oviduct which opens lateroventrally. Many small ovocytes and a few larger ova are present in each gonad. The largest specimen was peculiar in having a single ovary in ventral side of body immediately posterior to the brain, in position where spermaries are found in many species. The male is as yet unknown.

Geographical distribution: The three specimens from the Beebe 8-mile cylinder were taken at depths of about 1,400 to 1,800 metres. Reported by Wheeler from the South Atlantic ocean west of South Africa. The type specimen was obtained west of Ireland at a depth of about 2,000 metres, indicating a wide distribution in both the North and South Atlantic oceans.

2. *Protopelagonemertes beebei* sp. nov.
(Figs. 25, 34).

The collection contained one specimen similar in general appearance to medium sized individuals of *P. hubrechti*, except flatter, but differing in having only 19-21 proboscidial nerves and in other morphological details as noted below.

Body elongate oval, pointed at both ends, flattened except at anterior end. Size of type specimen: 24 mm. long, 7 mm. wide and somewhat more than 2 mm. thick. Body walls thicker than in most bathypelagic species, both circular and longitudinal layers being well developed even on lateral margins; cephalic musculature particularly thick, with very strong muscular bands providing a firm proboscis insertion anterior to brain.

Color in life orange yellow, with paler lateral margins; color results mainly from globules in intestinal epithelium, thus leaving a longitudinal median dorsal band of creamy white; proboscis whitish.

Mouth and proboscis opening united; proboscis sheath about seven-eighths as long as body, composed of interlacing spiral and longitudinal fibers. Proboscis longer than body, with 20 nerves in most sections of an-

terior chamber, but with apparently one more or one less at intervals, due to variations in the interneural plexus; nerves form continuous ring in basis region; retractor passes through dorsal wall of sheath to become anchored in dorsal body wall. Basis of typical curved form and bears a dozen or more conical, toothlike stylets. Accessory stylets were not found in this specimen.

Esophagus slender, leading to remarkably voluminous stomach with much convoluted walls posterior to brain commissures. Pylorus both long and broad; caecal diverticula and upwards of 40 pairs intestinal diverticula have both dorsal and ventral branches, with lobes above and beneath the nerve cords.

Dorsal vessel large, passing beneath proboscis sheath near posterior end of pylorus to unite with lateral vessels at posterior end of body.

Brain large; nerve cords each with single fibrous core; dorsal nerve conspicuous in all sections.

Reproductive organs: Female with upwards of 30 pairs of ovaries, the most anterior pair situated on the ventral side of nerve cords immediately posterior to brain. Anterior gonads small, with only one or two large ova, but in middle of body gonads are very large, arching above nerve cords to open ventrolaterally. Each ovary contains several large ova and many small ovocytes, as well as a basal syncytium containing numerous small nuclei. Male unknown.

Geographical distribution: Known only from the Beebe eight-mile cylinder off Bermuda; taken at a depth of 1,646 m.

The species is named in honor of Dr. William Beebe, Director of the Bermuda Oceanographic Expeditions, whose ability and industry have made the Bermuda trawling area the most thoroughly explored portion of all the oceans.

<div align="center">

Genus *Plotonemertes* Brinkmann.

3. *Plotonemertes adhaerens* Brinkmann.

Brinkmann, 1917, 1917a; Coe, 1926.

(Figs. 1, 7, 8, 14, 15, 22, 26, 27, 36, 37-42).

</div>

This species, of which only a single specimen has been hitherto reported, was represented by no less than 27 individuals in the collections studied. With the exception of *Nectonemertes mirabilis* it is evidently the most abundant species in the Bermuda area. Males, females and sexually immature individuals were represented.

The smallest specimen measured only 6 mm. in length and the largest 20 mm. The usually strongly recurved posterior extremity increases the difficulty of accurate measurement. Some of the variations in size and proportions are here indicated in millimeters: 6 x 1.5, 7 x 2, 7 x 2.5, 8 x 2.5, 10 x 3, 10 x 2, 11 x 2, 12 x 2, 12 x 3, 13 x 1.5, 13 x 2, 14 x 3, 15 x 2.5, 15 x 3, 16 x 5, 19 x 6, 20 x 5. The type specimen measured 30 x 9 mm. In most specimens the body is elongated oval or club-shaped, tapering gradually posteriorly, and usually with the flattened posterior end strongly recurved dorsally or, less frequently, ventrally.

Mouth and proboscis opening separate, the former usually with protruding circular lips due to partly everted stomach. Intestine with upwards of 50 pairs of much lobed diverticula, each with distinct dorsal and ventral branches; caecum with 6 pairs of similar diverticula. Proboscis sheath three-fourths to seven-eighths as long as body, composed of interlacing longitudinal and spiral fibers; proboscis relatively larger than in other bathypelagic forms and fully twice as long as body; attached posteriorly near end of dorsal wall of proboscis sheath. Number of proboscidial nerves variable, usually 26-28, but in some individuals only 24 or 25 were found

and in one specimen there were 30 distinct nerves anteriorly and only 25 farther back, while another had 28-34, of which several were smaller than the others. The variation is evidently due to the irregular distribution of nerves in the interneural plexus. Stylet basis curved at both ends, bearing numerous conical stylets; 6 small pouches each contain several more or less perfectly formed accessory stylets (Figs. 41, 42).

Lateral nerve cords with main ventral core and small, imperfectly separated, dorsal core; in some specimens dorsal core not distinguishable except near origin of dorsal peripheral nerves.

The glandular cutaneous organ found by Brinkmann on the ventral surface of the male occurs in both sexes, but is more highly differentiated in the male. This organ consists of deep convolutions of the surface epithelium, the lateral pair of folds being deeper than the others. In certain states of contraction this organ projects at an angle from the ventral surface when the body is recurved dorsally and may serve as an organ for the adhesion of the two sexes, as Brinkmann has suggested. The organ is not only highly glandular but is doubtless sensory as well, since it receives large branches from the adjacent lateral nerve cords.

Reproductive organs: Male provided with an irregular row of 7-11 spermaries opening ventrally on each side of body back of head; female with upwards of 30 pairs of narrow ovaries between intestinal diverticula and dorsal to lateral nerves; each ovary has several large ova and numerous small ovocytes.

Geographical distribution: The specimens here recorded were taken at depths of 1,300-1,800 m. on 16 occasions in the Beebe eight-mile area, while the type specimen was found near the middle of the North Atlantic (47° 34′ N. Lat., 43° 11′ W. Long.) at a depth of 2,000 m.

4. *Plotonemertes aurantiaca* sp. nov.
(Figs. 19, 20, 33, 43).

This new species of *Plotonemertes* differs from *P. adhaerens* in configuration of the body, in number of proboscidial nerves, in character of proboscis armature, in length of proboscis sheath, in character of glandular organ, in having but a single core in each of the lateral nerve cords and in other details noted below.

Body elongate, about half as thick as wide, flattened ventrally and rounded dorsally except in posterior sixth of body which is recurved behind glandular organ and flattened into a distinct caudal fin (Figs. 19, 20). Length of type specimen, 40 mm., width 11 mm., thickness in median line 5-7 mm. near middle of body and 1 mm. or less in caudal fin.

Surface epithelium well preserved over entire body; basement layer moderately thin and corrugated; muscular walls on lateral margins very thin; dorso-ventral muscles between intestinal diverticula with some giant fibers in addition to ordinary muscle cells.

Mouth separate from proboscis opening; proboscis sheath about two-thirds to three-fourths as long as body; composed of interlacing longitudinal and circular fibers except ventrally, where longitudinal fibers are few in number; proboscis very large, and much longer than body; 21 distinct proboscidial nerves. Epithelium with prominent papillae. Stylet basis pistol-shaped, with curved, rounded base and nearly straight principal axis; stylets lost before examination, but the rounded pockets on face of basis indicate that they were numerous (Fig. 33).

Color in life bright orange, with yellow margins and caudal fin and deep yellow proboscis. Color well preserved after several months in alcohol.

Stomach close behind mouth, walls much folded and evidently capable of extension as circular lips around mouth opening; pylorus wide but flat;

caecal and intestinal diverticula much lobulated, with ventral branches beneath nerve cords; 40-50 pairs intestinal diverticula.

Cutaneous glandular organs widely separated from each other in the female; epithelial convolutions with deep folds beneath basement membrane (Fig. 43); provided with large nerves from both median and ventral sides of lateral nerve cords.

Lateral nerve cords consist of but a single fibrous core; with the usual commissure on dorsal side of rectum and posterior to anastomosis of blood vessels.

Dorsal vessel large, enters rhynchocoel near posterior end of brain region, passes beneath proboscis sheath anterior to intestinal region and unites with lateral vessels at posterior end of body.

Parasites: The rhynchocoel contained many large gregarines.

Reproductive organs: Type specimen was female with 26-29 ovaries on each side (Fig. 43) situated close beside and above the nerve cords. Ova large, 3-6 in each gonad; oviducts open on ventral surface directly beneath lateral nerve cords. Male unknown.

Geographical distribution: Known only from the Beebe 8-mile area; depth 1,463 m.

Genus *Crassonemertes* Brinkmann.

5. *Crassonemertes robusta* Brinkmann.

Brinkmann, 1917, 1917a; Coe, 1926; Wheeler, 1934.

(Figs. 17, 21, 35).

The collections contained two specimens of this thick-bodied nemertean; only two others have been previously recorded. One specimen measured 16 mm. in length, 7.5 mm. in width and 2 mm. in thickness after preservation; the other was 23 x 12 x 2 mm.; the type specimen was 25 mm. long, 10 mm. wide and 4.5 mm. thick.

Mouth and proboscis opening separate; proboscis sheath extends nearly entire length of body; composed of interlacing spiral and longitudinal muscle fibers, with a tendency toward separate layers posteriorly; proboscis large, armed with rather large, moderately curved basis, bearing many sharply conical stylets and about a dozen shallow pouches of imperfectly formed reserve stylets; 20-23 proboscidial nerves; retractor passes through dorsal wall of sheath to become interlaced with muscles of dorsal body wall.

Upwards of 40 pairs of intestinal diverticula and 5 pairs of caecal diverticula profusely branched, both above and below lateral nerve cords. Nerve cords with single fibrous core anteriorly, but with small and incompletely separated dorsal core posterior to middle of body.

Reproductive organs: Female with 20-30 or more pairs of ovaries on dorsal side of nerve cords, opening lateroventrally. Male unknown.

Geographical distribution: Evidently widely distributed in the North Atlantic, the type specimen coming from northwest of Great Britain (57° 41' N. Lat., 11° 48' W. Long.) at a depth of about 1,666 m.; and the Bermuda specimen from a depth of about 1,100 m. Wheeler reports this species from off the west coast of Africa (6° 55' N. Lat., 15° 54' W. Long.) at a depth of less than 800 m.

Genus *Pachynemertes* nov.

The collections contained two specimens which have a superficial resemblance to *Crassonemertes robusta* but differ so widely in internal anatomy as to require the establishment of a separate genus in the family Planktonemertidae.

The genus *Pachynemertes* is diagnosed as follows: Body short, thick,

rounded; with slightly differentiated caudal fin; mouth and proboscis opening separate; intestinal diverticula without ventral branches; proboscis sheath composed of interlaced fibers; lateral nerve cords separated from ventral body wall by gelatinous tissue only.

6. *Pachynemertes obesa* sp. nov.
(Figs. 50, 51).

A single example of a short and thick-bodied nemertean bore the label "Grenadine animal," doubtless referring to the similarity of its shape to a miniature hand grenade. This species differs from *C. robusta* in the number of proboscidial nerves, in shape of stylet basis, in having less profusely branched intestinal diverticula, in the shorter length of the proboscis sheath and in other anatomical details.

Body after preservation short, oval, thick, with thin lateral margins posteriorly, continuing into a slightly bilobed caudal fin (Fig. 50). Length of type specimen 16 mm., width 8 mm., thickness 5 mm. Color in life unknown; body opaque and firm after preservation. Body walls thick on dorsal and ventral surfaces, but thin laterally.

Proboscis sheath extends about three-fourths the length of the body; circular, spiral and longitudinal fibers interlaced to form a single musculature. Proboscis slender; longer than body; provided with 14 distinct nerves and, in some sections, two additional ones of smaller size; stylet basis sharply curved, armed with upwards of 20 conical teeth (Fig. 51).

Mouth and proboscis opening well separated; mouth with protruding lips (Fig. 50); stomach much convoluted; slender pylorus of moderate length; about 35 pairs of intestinal diverticula, which are lobed, but not distinctly branched; ventral branches rudimentary, allowing lateral nerve cords to lie close to ventral body wall.

Dorsal vessel extends in rhynchocoel for a short distance, then passes beneath the proboscis sheath and continues posteriorly to join lateral vessels at posterior end of body.

Brain of moderate size; lateral nerve with single fibrous core.

Reproductive organs: The type specimen was an adult female with several ova in each of upwards of 30 pairs of ovaries.

Geographical distribution: Known only from the Bermuda area, where a single specimen was obtained at a depth of about 1,600 m.

Genus *Paradinonemertes* Brinkmann. (Emended).

According to the diagnostic characters of this genus as formulated by Brinkmann (1917), the mouth is situated behind the brain. The six specimens of a closely related species (*P. wheeleri*) from this collection, undoubtedly belonging to the same genus, prove that the position of the mouth relative to the brain is variable, depending on the state of contraction of the anterior portion of the body. Consequently the generic diagnosis must be emended to read: Body much flattened; mouth somewhat widely separated from rhynchodeal opening, situated anterior, ventral or slightly posterior to brain according to state of contraction of anterior portion of body; proboscis sheath extends into posterior third of body, its musculature composed of interwoven fibers.

7. *Paradinonemertes wheeleri* sp. nov.
(Figs. 2, 3, 9, 10, 11, 23, 45-49).

The collections contained 6 excellently preserved specimens of a new species of *Paradinonemertes*, the individuals of which differ from those

of *P. drygalskii* Brinkmann in many important respects, particularly in length of proboscis sheath, armature of proboscis, number of spermaries, character of lateral nerve cords and position of mouth.

Body translucent, broad, flat and thin, with broad caudal fin continuous with thin lateral margins of body; about 3 to 4 times as long as wide; measurements of several specimens were as follows: males, 14 x 5 x 2, 23 x 5.5 x 2; females, 11 x 3 x 2.5, 11 x 4 x 1.5, 13 x 4 x 2, 18 x 5 x 2, 42 x 15 x 2 (Figs. 2, 3, 9, 16, 23, 45, 46).

Mouth situated on ventral side of head; widely separated from proboscis opening but anterior to brain commissures except when cephalic musculatures are abnormally contracted, with protruding lips in most preserved specimens, leading directly to convoluted walls of stomach. In specimens having the proboscis fully retracted the mouth lies well anterior to the brain; the lips are widely protruded in the preserved specimens; the stomach walls have but few convolutions; 40-50 pairs of lobulated intestinal diverticula, with small or rudimentary ventral branches not extending beneath nerve cords.

Proboscis sheath about two-thirds to three-fourths as long as body, with interlaced muscular walls; proboscis about as long as body, with 12 or 13 distinct nerves; basis strongly curved, with numerous rather sharply conical stylets (Fig. 47). Proboscis sheath tapers to a point posteriorly and terminates in the parenchyma between the intestinal diverticula and without any fibrous connection with the dorsal body wall. Retractor muscles of proboscis are attached to sheath only.

Cephalic blood lacunae rather small; dorsal vessel enters rhynchocoel close behind ventral brain commissure, passes beneath the proboscis sheath a short distance farther back and continues posteriorly to join the lateral vessels at the end of the body.

Lateral nerve cord with small and imperfectly differentiated dorsal core.

Reproductive organs: Male with 3-5 pairs of spermaries opening on ventral surface behind brain and between anterior caecal diverticula. Female with 30-36 or more pairs of ovaries, each containing, when mature, 1 to 5 large ova and several small ovocytes; situated dorsally and laterally to nerve cords. (Figs. 45, 46).

Geographical distribution: Known only from the Beebe eight-mile area off Bermuda, where it was obtained at depths of 1,400-1,800 m.

The species is named in honor of Dr. J. F. G. Wheeler, Director of the Bermuda Station for Biological Research and a leading investigator of the bathypelagic nemerteans.

Genus *Planonemertes* Coe.

8. *Planonemertes labiata* sp. nov.

(Fig. 52).

Two specimens of this new form were obtained. One of these was an adult male measuring after preservation 21 mm. in length, 8 mm. in width and 2 mm. in greatest thickness. The other was a female about 16 mm. long and 6 mm. wide.

Body elongate oval, widest anterior to middle region, narrowing gradually toward posterior end; rather thin even when strongly contracted, and with very thin lateral margins continuous with thin caudal fin.

Color in life unknown; body translucent after preservation.

Body walls much thinner on dorsal surface than in many other forms and very thin laterally. Much gelatinous tissue between the muscle bundles and between the other organs in anterior half of body; dorso-ventral muscles

well developed laterally and posteriorly. Ventral muscle plate several times as thick as dorsal.

Proboscis sheath extends about four-fifths the length of the body; walls composed of three fairly distinct muscular layers, except for a short distance posterior to proboscis attachment where longitudinal and spiral fibers are interlaced. Farther back there is a well marked differentiation into inner circular, longitudinal and outer circular or spiral musculatures, although there are some spiral fibers extending between the inner and outer layers; inner circular layer about as thick as two other layers combined.

Only the posterior portion of the proboscis was retained. This part remained attached by the strong retractor to the wall of the sheath a short distance anterior to the end of the rhynchocoel (Fig. 52). The longitudinal fibers of the retractor were interlaced and in part continuous with the longitudinal musculature of the proboscis sheath; other fibers interlaced with those of the two other muscular layers of the sheath. Posterior to the retractor attachment the sheath becomes smaller and with thinner walls and ends in the gelatinous tissue between the intestinal diverticula. No statements can be made as to the armature of the proboscis or the number of proboscidial nerves.

Mouth subterminal, separate from proboscis opening; with enormously swollen lips in type specimen after preservation, due to strong contraction of cephalic tissues and partial eversion of stomach during extrusion of proboscis (Fig. 52). Caecal and intestinal diverticula much lobulated, but without ventral branches. Caecal diverticula extend forward to brain region. There are upwards of 20 pairs of intestinal diverticula.

Dorsal vessel enters rhynchocoel immediately behind brain, then passes through the ventral wall of the sheath after a short distance and continues posteriorly to join lateral vessels at posterior end of body.

Brain large; nerve cords with small but distinct dorsal fibrous core. The nerve cords are situated about midway between median line and lateral margins of body.

Reproductive organs: The type specimen was adult male with two clusters of small spermaries on the ventral side of the head, immediately posterior to the brain. (Fig. 52). The two clusters lie close to the median line; each contains about 6 to 8 thin-walled spermaries with slender sperm ducts, the ends of which protrude slightly from the body wall. The female has the usual arrangement of paired ovaries between the intestinal diverticula.

Geographical distribution: Known only from a depth of about 1,800 m. at the Bermuda trawling area. The single previously described species of the genus was taken in the Pacific ocean.

<div align="center">

Genus *Phallonemertes* Brinkmann.

9. *Phallonemertes murrayi* Brinkmann.

Brinkmann, 1913, 1917, 1917a; Coe, 1926.

(Figs. 4, 24, 44).

</div>

Two specimens of this highly modified species were obtained by the Bermuda expeditions. One of these was a large mature male measuring 40 mm. long, 10 mm. wide and about 2 mm thick; the second was a young male 18 mm. long and 5 mm. wide.

Body elongated, with parallel sides, terminating posteriorly in a broad caudal fin, usually recurved but not sharply demarcated from body (Figs. 4, 24). Previously reported specimens varied from 34-61 mm. in length and 5-10 mm. in width. Color in life pink or red except caudal fin which is

translucent and colorless. Color due in part to numerous pigmented vacuoles in alimentary canal.

Mouth and proboscis opening separate; when the proboscis is partially everted the cephalic tissues may become so strongly contracted that the mouth with its circular protruding lips may come to lie beneath the brain and is thus widely separated from the proboscis opening. There are upwards of 40-50 pairs of intestinal diverticula and 5 pairs of caecal diverticula, somewhat lobed but without distinct ventral branches. Proboscis sheath about three-fifths as long as body, with interlacing fibers; proboscis armed with rather small, sharply curved basis bearing numerous conical stylets, together with several shallow pouches of reserve stylets; 13-17 proboscidial nerves, with broad interneural plexus.

Lateral nerve cords with distinct dorsal core; dorso-lateral nerves relatively large, with metameric connections with dorsal peripheral branches of nerve cords.

Reproductive organs: Male with 4-7 pairs spermaries in single row on each side of the body immediately posterior to the brain; each of these when fully mature is provided with a long tubular spermatic duct projecting as a penis far beyond the surface of the body (Fig. 44). Female with 20-30 or more pairs of ovaries, each of which produces upwards of a dozen ova and opens on ventral surface lateral to nerve cord.

Geographical distribution: Depth 1,500-1,800 m.; previously reported from various localities in the North Atlantic from Lat. 35° to near the southern point of Greenland, at depths of 1,600-2,000 m.

<p style="text-align:center">Genus Chuniella Brinkmann.</p>

<p style="text-align:center">10. Chuniella lanceolata Brinkmann.</p>

<p style="text-align:center">Brinkmann, 1917, 1917a; Coe, 1926.</p>

The single specimen of this species contained in the collections is of particular interest because it represents the female of a form in which the male only was previously known.

Body elongated, not much flattened, narrowed and pointed posteriorly, without caudal fin; length of Bermuda specimen 5 mm., width 1 mm.; type specimen 10 x 2.25 mm. Body walls with thick dorsal and ventral longitudinal muscle plates, some of the muscular fibers being of comparatively gigantic size; circular muscular layer very thin.

Mouth and proboscis opening separate; upwards of 30 pairs unbranched intestinal diverticula and 5 pairs of similar caecal diverticula. Proboscis sheath nearly as long as body, walls of separate muscular layers; many of the spiral fibers are remarkable for their relatively enormous size and distinct cross striations. Proboscis large, about twice as long as body, with relatively large, curved basis and obtusely conical stylets; 21-23 proboscidial nerves.

Brain very large as compared with size of body; lateral nerve cords close against ventro-lateral body wall, with single fibrous core except for imperfectly differentiated dorsal core anteriorly.

Reproductive organs: Male with about a dozen spermaries in an irregular row on each side of body immediately posterior to brain. Female with upwards of 20 pairs of ovaries, each with two or three large ova.

Geographical distribution: The specimen here recorded came from a depth of 1,646 m.; the type specimen was taken in the North Atlantic southwest of Ireland at a depth of 1,000 m.

Genus *Nectonemertes* Verrill.

11. *Nectonemertes mirabilis* Verrill.

Verrill, 1892; Brinkmann, 1917, 1917a; Coe, 1926; Wheeler, 1934.

(Figs. 12, 13, 32).

Throughout the entire extent of the North Atlantic ocean this is by far the commonest of all species of bathypelagic nemerteans. A total of 125 specimens has been previously reported. It was represented in the Bermuda collections by 32 specimens, about equally divided between the two sexes and including several young individuals, the smallest being only 8 mm. long. All conformed with previous descriptions of the growth stages and adults. They were taken at various depths between 1,000 and 1,850 m., indicating a considerable vertical range in a single locality. Including one large male collected off the coast of Cuba by the Bingham Expedition, and not previously reported, the species is now known to extend through both the North and South Atlantic oceans from the latitude of southern Greenland, southward through the tropics to the latitude of South Africa.

Genus *Balaenanemertes* Bürger.

12. *Balaenanemertes minor* sp. nov.

(Figs. 5, 6, 53).

The single individual of this species found in the collections measured only 4 mm. in length, 2 mm. in width and 1 mm. in thickness, although it was a fully mature female with ripe ova. If this specimen is truly representative of the species, the individuals belonging to it are considerably smaller than those of any other known bathypelagic form.

The species somewhat resembles *B. lobata* and *B. musculocaudata* but differs in position and size of tentacles, in number of proboscidial nerves, in number of intestinal and caecal diverticula and in other details.

Body small, oval, somewhat narrowed posteriorly with distinct, bilobed caudal fin; tentacles small, situated well back of head, with imperfectly developed musculatures. Body walls extremely thin, with thin basement layer; very little parenchyma between intestinal diverticula and body walls.

Proboscis sheath nearly as long as body, with delicate musculature in two layers, inner longitudinal and outer spiral, except on ventral side, where longitudinal layer is lacking. Proboscis large, with 14 distinct nerves in most sections, although one of these may be lost in the interneural plexus in some sections and an additional one may be represented in others. Longitudinal muscles of retractor interwoven with both longitudinal and spiral layers of dorso-lateral wall of sheath at a point about four-fifths the distance from anterior to posterior end of body. Proboscis armed with curved basis of typical form bearing numerous small conical stylets, also with at least three shallow pouches of accessory stylets, of which as many as six may be present in one pouch.

Mouth well separated from proboscis opening; esophagus wanting; stomach simple, walls not convoluted in the type specimen; pylorus short; caecum with median branch reaching to brain and one or two pairs of voluminous, lobed diverticula, of which the anterior lobes reach the brain; pylorus in this specimen opens into dorsal wall of intestine in such a position as to make it uncertain whether the second pair of diverticula belong to caecum or intestine; about 13 pairs lobed intestinal diverticula, without ventral branch.

Lateral nerve cords lie close to latero-ventral body walls, with single fibrous core; with usual commissure ·above rectum; nerve cord muscles small.

Dorsal vessel ends blindly after a short distance in rhynchocoel. Cephalic lacunae large, with large corpuscles.

Reproductive organs: Female with 4-5 pairs of ovaries, each with single enormous ovum when mature. Oviducts large, opening ventrally between nerve cords and median line; ovarian wall much convulated after discharge of ovum (Fig. 53). Male unknown.

Geographical distribution: Known only from Beebe eight-mile area off Bermuda, where it was taken in a net drawn at a depth of about 549 m. None of the other nemerteans in this area was found so near the surface, but other species of the same genus have been collected at various localities at similar depths as well as very much deeper.

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EXPLANATION OF THE PLATES.

The lettering on the plates includes the following abbreviations:

a—anus
ac—anterior chamber of proboscis
br—brain
cg—cerebral ganglia
dv—dorsal blood vessel
ic—intestinal caeca
id—intestinal diverticula
go—glandular organ
ln—lateral nerve cord
lv—lateral blood vessel
m—mouth

ov—ovaries
p—proboscis
pa—proboscis attachment musculature
pc—posterior chamber of proboscis
ps—proboscis sheath
rc—rhynchocoel
ro—rhynchodeal opening
sb—stylet basis
sp—spermaries
st—stomach
t—tentacle

PLATE I.

Figs. 1-15. Photographs of preserved specimens; all except Fig. 5 approximately one-third larger than natural size.

Fig.   1. *Plotonemertes adhaerens.* Body recurved dorsally; proboscis everted; lips protruding.

Figs. 2, 3. *Paradinonemertes wheeleri.* Male and female; body strongly contracted and much flattened.

Fig.   4. *Phallonemertes murrayi.* Male, showing 6 pairs of spermaries.

Figs. 5, 6. *Balaenanemertes minor.* Female with large ovaries and everted proboscis.

Figs. 7, 8, *Plotonemertes adhaerens.* Proboscis partially everted.

Figs. 9, 10. *Paradinonemertes wheeleri.* Female and young male.

Fig. 11. Same. Large individual with extruded proboscis.

Figs. 12, 13. *Nectonemertes mirabilis.* Young male and female, latter with extruded proboscis.

Figs. 14, 15. *Plotonemertes adhaerens.* Females with proboscis retracted.

PLATE II.

Figs. 16-27. Photographs of preserved specimens; all approximately one-third larger than natural size.

Fig. 16. *Protopelagonemertes hubrechti.* Female with everted proboscis.

Fig. 17. *Crassonemertes robusta.* Female with partially everted proboscis.

Fig. 18. *Protopelagonemertes hubrechti.* Very large female. Posterior extremity broken off.

Figs. 19, 20. *Plotonemertes aurantiaca.* Large female with everted proboscis. Posterior end of body sharply recurved dorsally in position of glandular organ.

Fig. 21. *Crassonemertes robusta.*

Fig. 22. *Plotonemertes adhaerens.*

Fig. 23. *Paradinonemertes wheeleri.* Large female showing intestinal diverticula.

Fig. 24. *Phallonemertes murrayi.* Male, showing six pairs of spermaries.

Fig. 25. *Protopelagonemertes beebei.* Body abnormally flattened; proboscis partially everted.

Fig. 26. *Plotonemertes adhaerens.* Body compressed.

Fig. 27. Same. Small individual with body strongly recurved dorsally.

PLATE III.

Fig. 28. *Protopelagonemertes hubrechti.* Very large female, showing dorsal and lateral keels; proboscis slightly everted; *A,* dorsal surface; *B,* lateral view; *C,* transverse section of body. Twice natural size.

PLATE IV.

Fig. 29. *Protopelagonemertes hubrechti.* Portion of proboscis, showing portions of anterior (*ac*) and posterior chambers (*pc*), stylet basis (*sb*) and position of accessory stylet pouches.

Fig. 30. Same. Stylet basis more highly enlarged.

Fig. 31. Same. One of the six pouches of accessory stylets.

Fig. 32. *Nectonemertes mirabilis.* Anterior portion of body of young male, showing small tentacles and the position of the spermaries (*sp*).

Fig. 33. *Plotonemertes aurantiaca.* Stylet basis.

PLATE V.

Fig. 34. *Protopelagonemertes beebei.* Female, showing partially everted proboscis (*p*), extent of proboscis sheath (*ps*) and position of ovaries (*ov*); *ic,* caecal diverticula.

Fig. 35. *Crassonemertes robusta.* Female, showing partially everted proboscis (*p*), extent of proboscis sheath (*ps*), ovaries (*ov*), stomach (*st*), and the profusely branched intestinal diverticula (*id*).

PLATE VI.

Fig. 36. *Plotonemertes adhaerens.* Male with everted proboscis, showing extent of proboscis sheath, position of spermaries (*sp*) and glandular organ (*go*). Posterior extremity recurved.

Figs. 37, 38. Same. Ventral and lateral views of glandular organ (*go*).

Figs. 39, 40. Same. Configuration of glandular organ when posterior extremity of body is sharply recurved dorsally.

Fig. 41. Same. Proboscis with stylet basis.

Fig. 42. Same. Stylet basis and the six pouches of accessory stylets.

PLATE VII.

Fig. 43. *Plotonemertes aurantiaca.* Female from ventral surface, showing small ovaries (*ov*) and the well-developed glandular organs (*go*).

Fig. 44. *Phallonemertes murrayi.* Male from ventral surface, showing extent of proboscis sheath (*ps*), arrangement of intestinal diverticula (*id*), position of mouth (*m*) and the six pairs of spermaries (*sp*), each with slender, protruded penis.

PLATE VIII.

Fig. 45. *Paradinonemertes wheeleri.* Male, showing extent of proboscis sheath (*ps*) and the three pairs of spermaries (*sp*).

Fig. 46. Same. Female, showing position of ovaries (*ov*); *m,* mouth; *cg,* cerebral ganglia; *dv,* dorsal vessel; *sb,* stylet basis.

Fig. 47. Same. Stylet basis and stylets.

PLATE IX.

Fig. 48. *Paradinonemertes wheeleri.* Female; left half from dorsal surface and right half from ventral surface, showing position of ovaries, oviducts (*od*) and intestinal diverticula (*id*); and extent of proboscis sheath (*ps*); *cg,* cerebral ganglia; *dv,* dorsal vessel; *ln,* lateral nerve cord; *lv,* lateral vessel; *sb,* stylet basis in proboscis.

Fig. 49. Same. Stylet basis.

Fig. 50. *Pachynemertes obesa.* Strongly contracted specimen, showing mouth and everted proboscis.
Fig. 51. Same. Outlines of stylet basis and stylets.

PLATE X.

Fig. 52. *Planonemertes labiata.* Outline of body of type specimen, showing enormously swollen lips surrounding the mouth (*m*), the clusters of cephalic spermaries (*sp*), intestinal diverticula (*id*), rhynchocoel (*rc*), and posterior end of proboscis (*p*).
Fig. 53. *Balaenanemertes minor.* Female with three very large, ripe ova; *od*, preformed oviduct; *ov'*, recently emptied ovary; *id*, intestinal diverticula; *m*, mouth; *pa*, attachment of proboscis near posterior end proboscis sheath (*ps*); *sb*, stylet basis in everted proboscis; *t*, minute tentacle.

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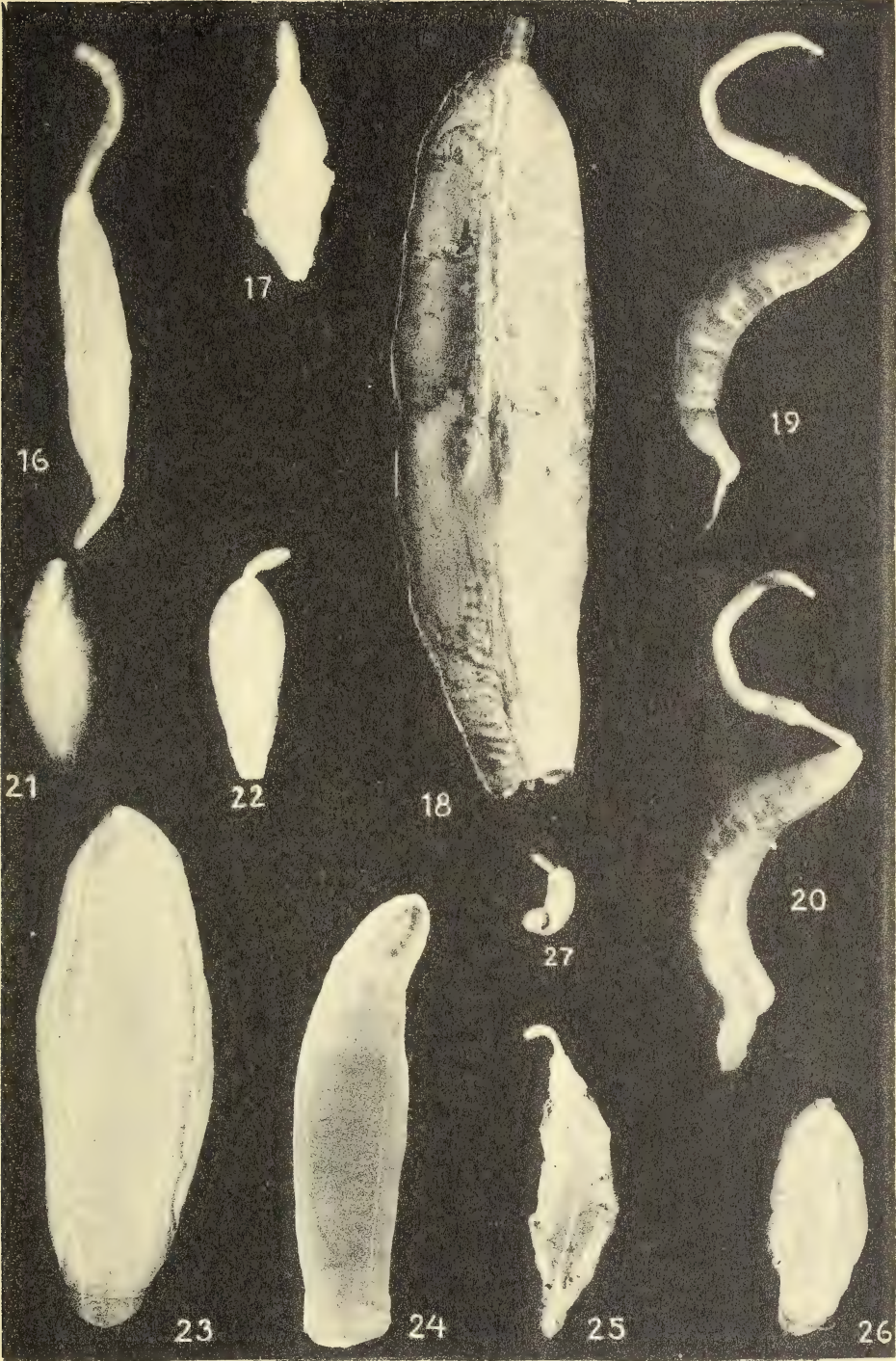
BATHYPELAGIC NEMERTEANS TAKEN IN THE YEARS 1929, 1930 AND 1931.

BATHYPELAGIC NEMERTEANS TAKEN IN THE YEARS 1929, 1930 AND 1931

PLATE V.

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L.KRAUSE DEL.

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BATHYPELAGIC NEMERTEANS TAKEN IN THE YEARS 1929, 1930 AND 1931.

PLATE VI.
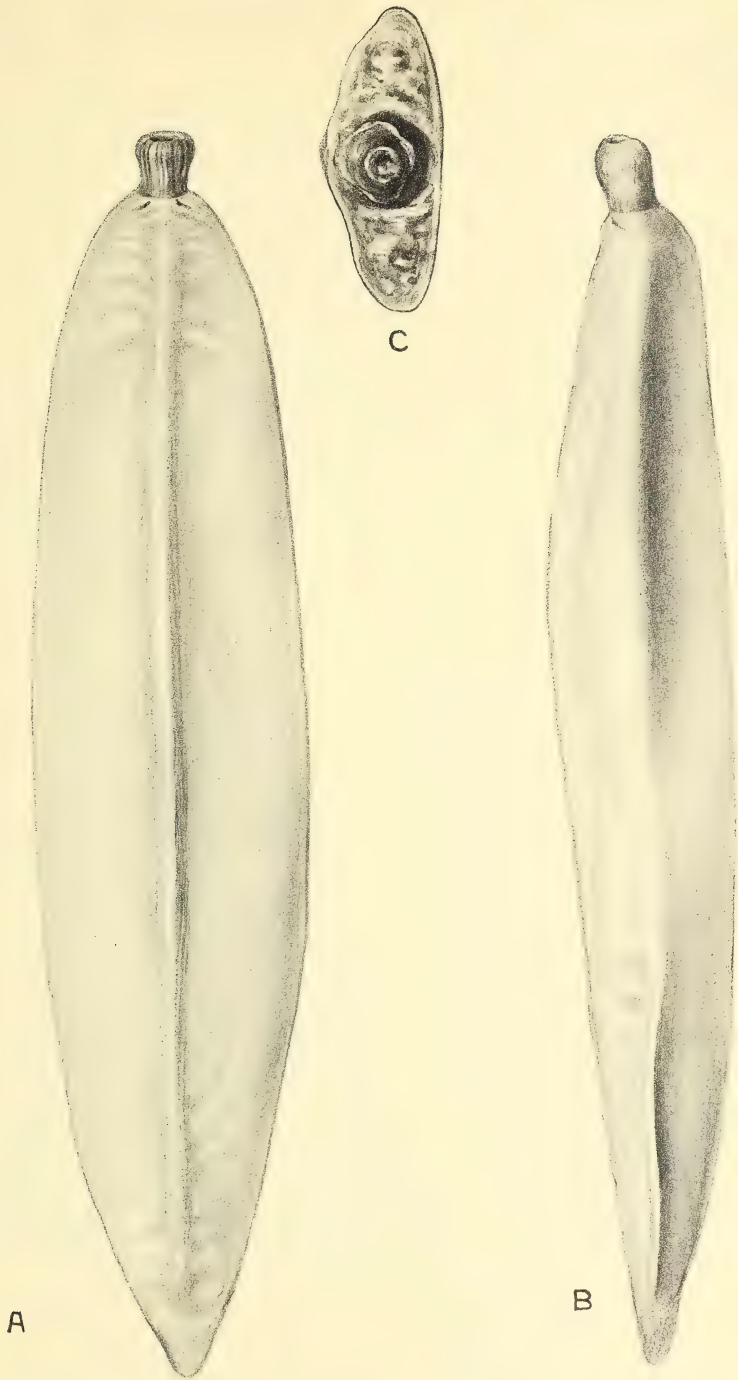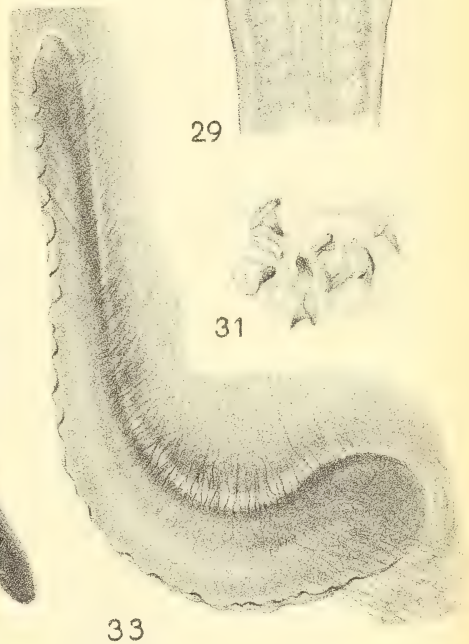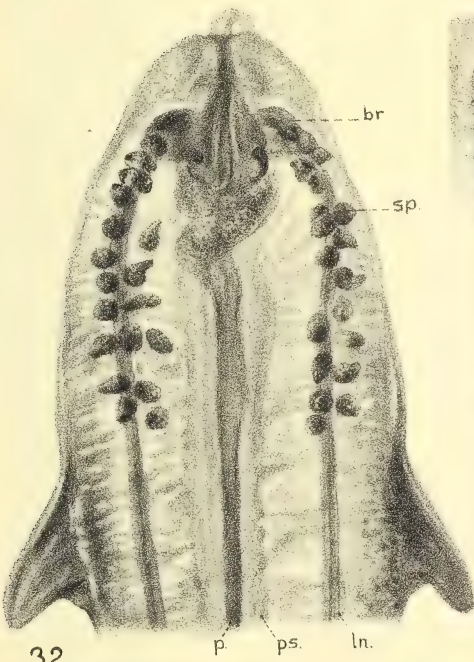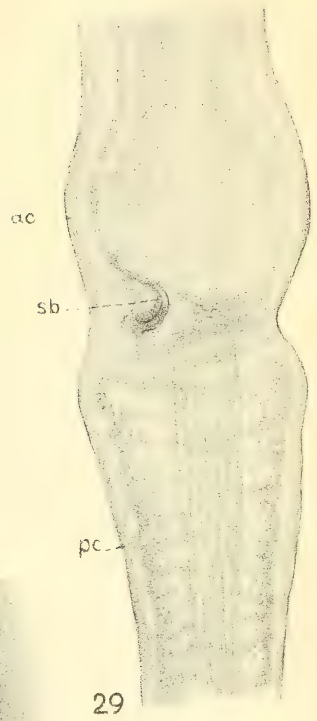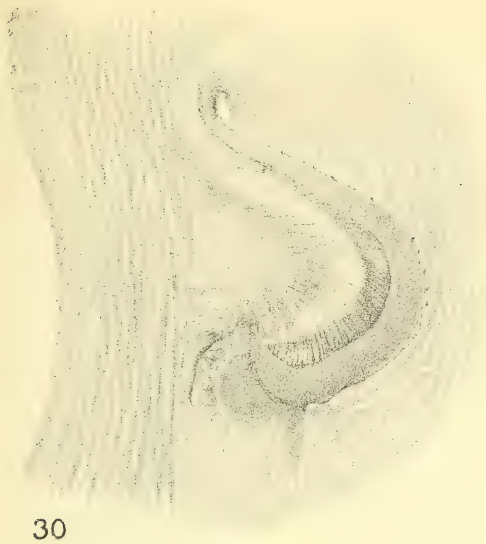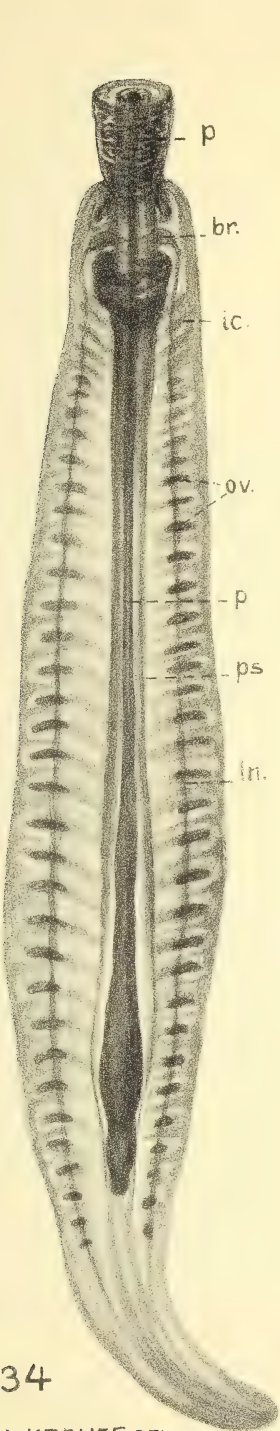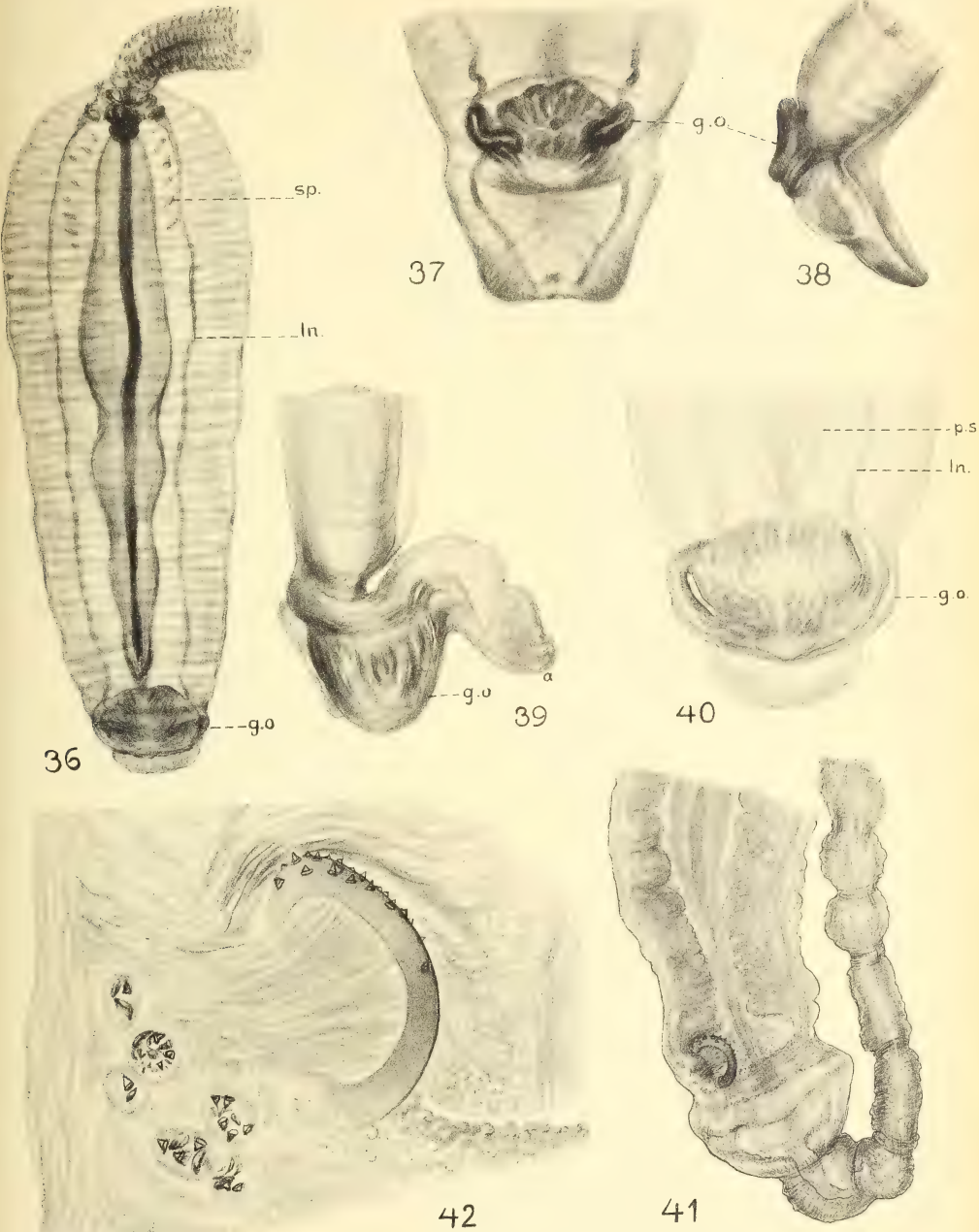
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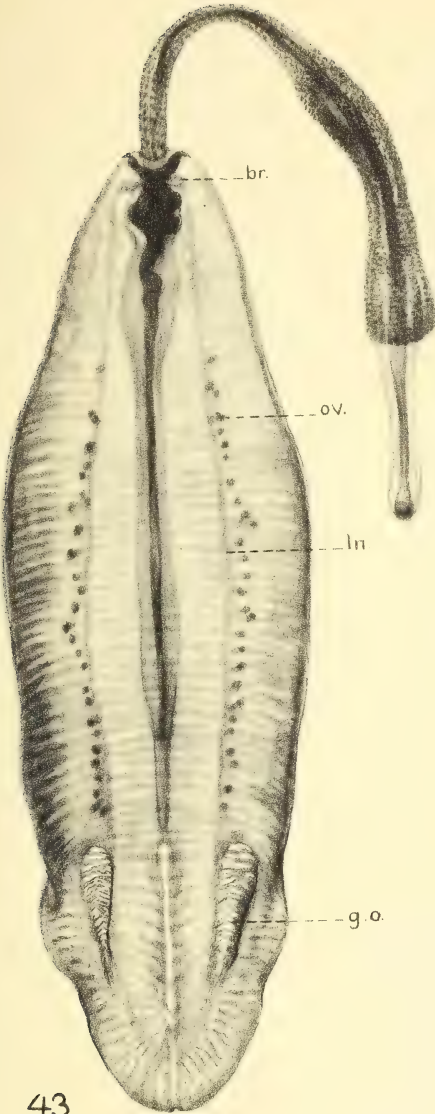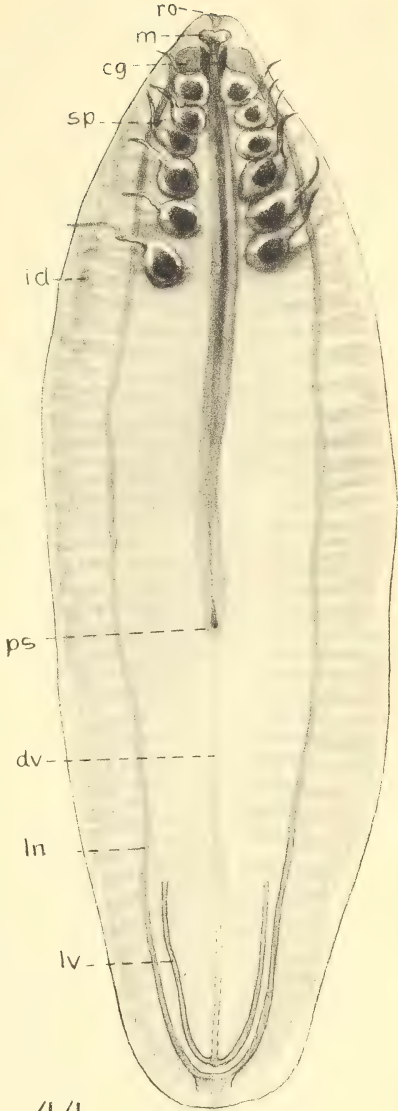
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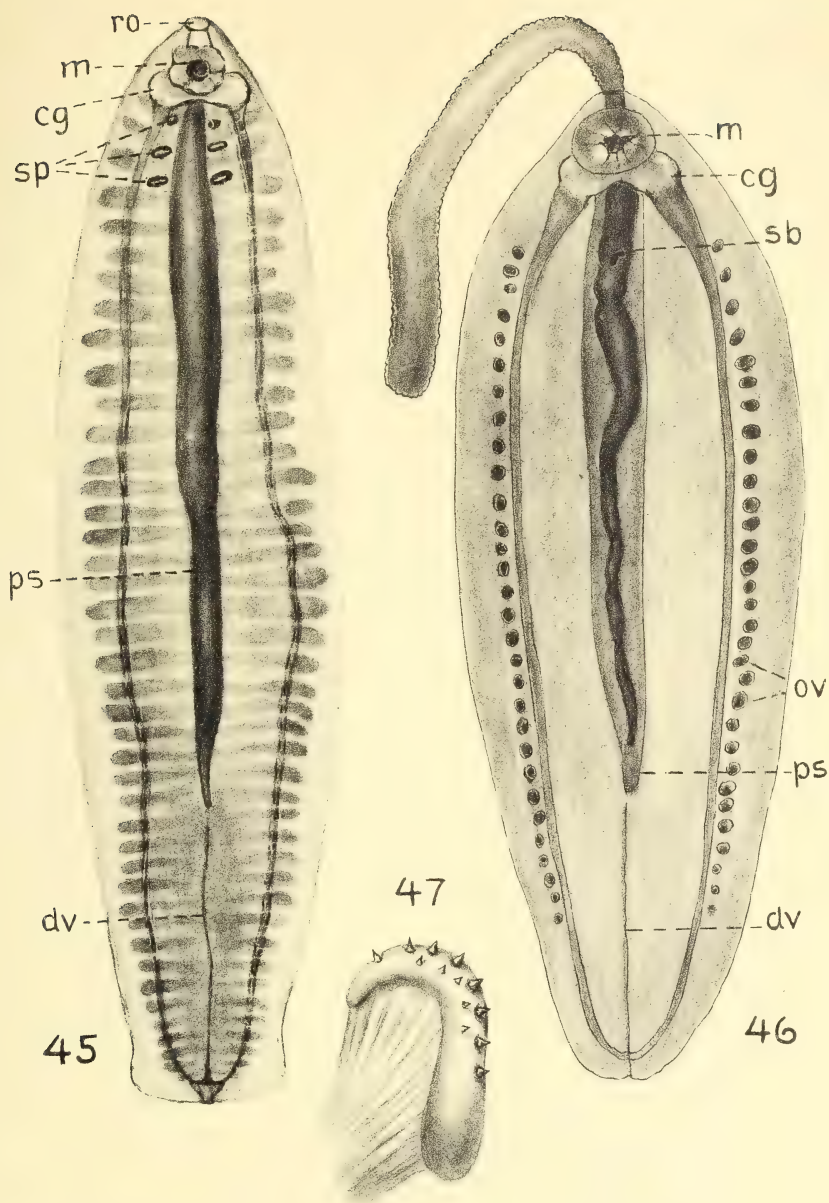
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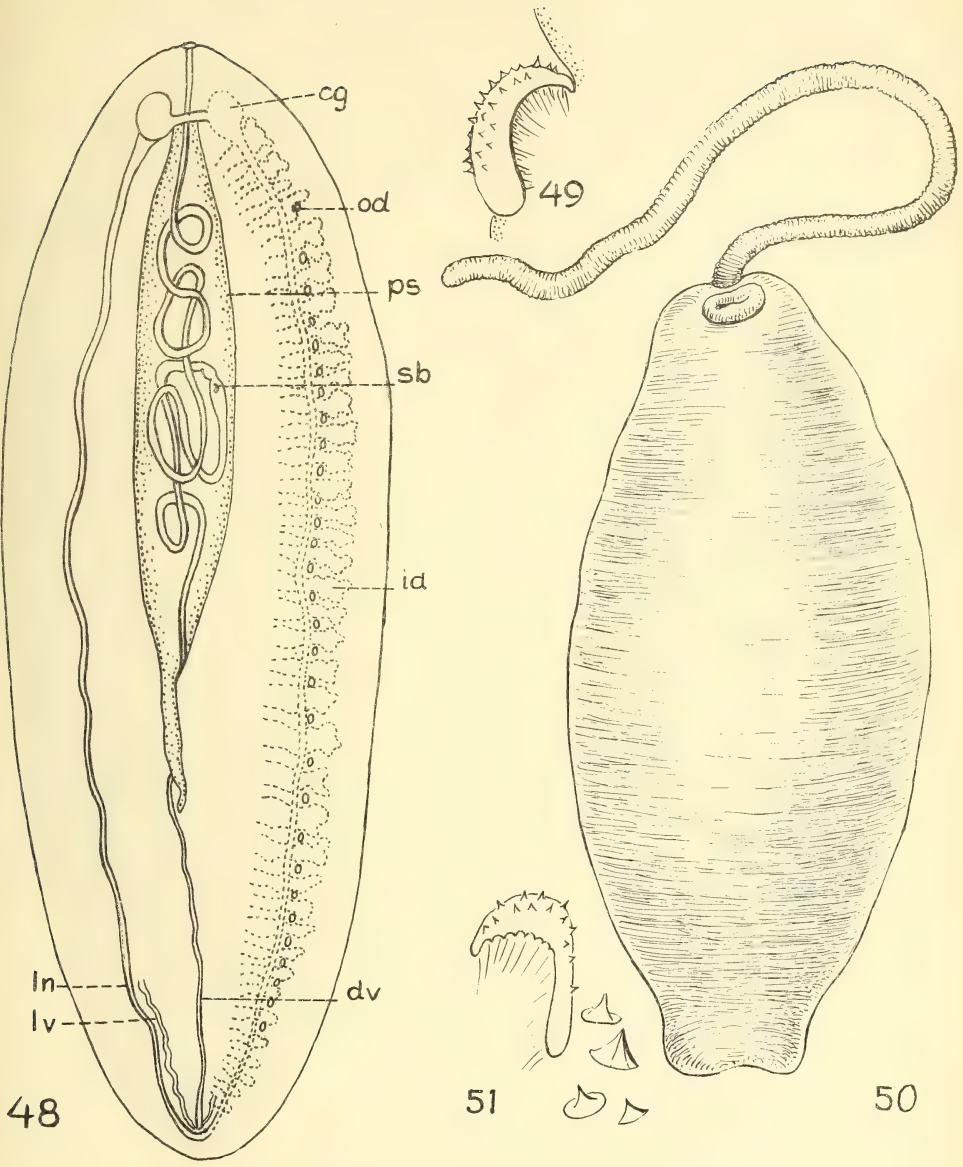
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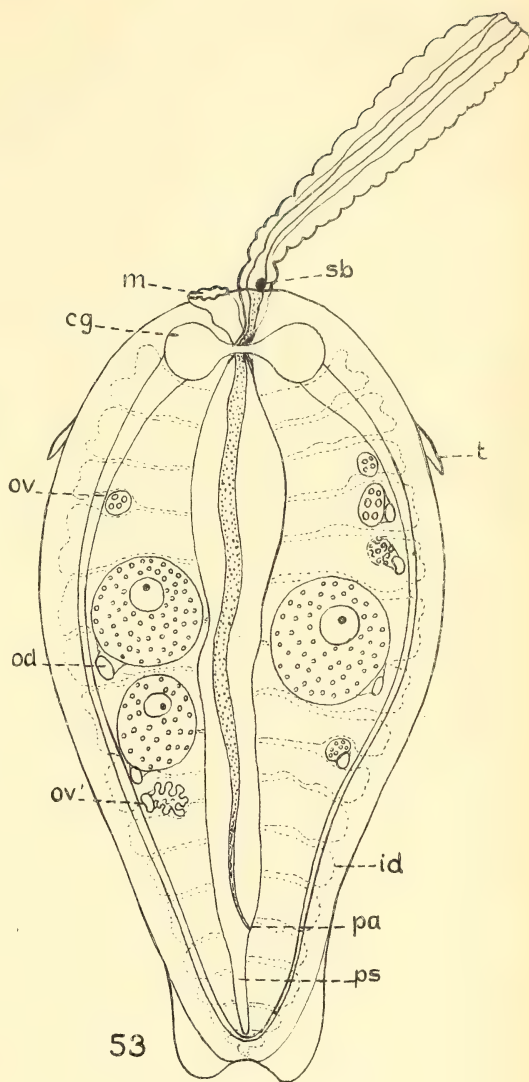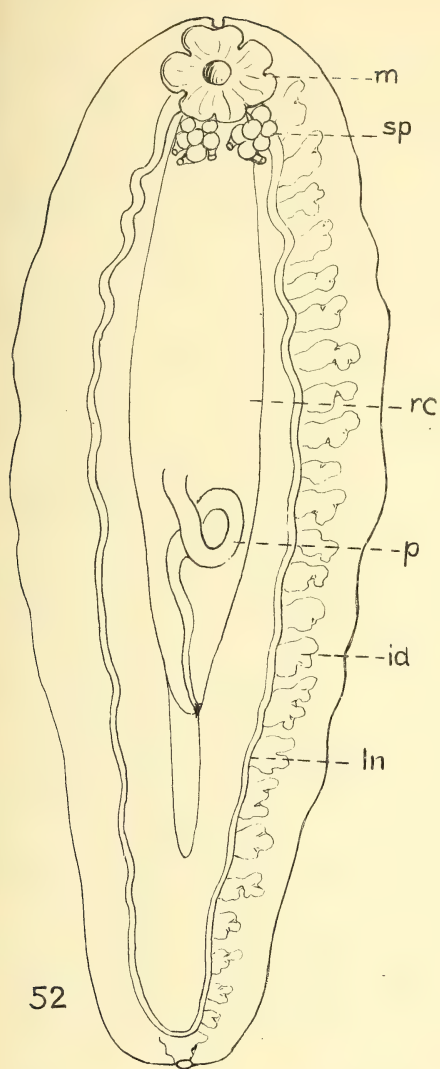
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10.

Tissue Culture and Explantation in Nature: A Review of Certain Experiments and Possibilities.

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INTRODUCTION.

The possible methods of operation of organic evolution have for long attracted the speculative faculties of biologists. Phenomena concerned with the general aspects, as well as special phases, have occupied prominent places in biological controversy. In spite of this great discussional activity on the part of students, there is good reason to suppose that many possibilities exist that have not been examined or even imagined. Until all such conceivable methods have been appraised, the extent of the effect of those whose reality is established must remain an open question.

The hypothesis subsequently set forth may serve as an example and undoubtedly numerous others could be developed. All such hypotheses must either be satisfactorily refuted or established in order to develop a thoroughly adequate and fully acceptable evolutionary scheme. The present discussion deals with a very special case, but, as with all such matters, its probable limits of application cannot be easily anticipated at this time.

The argument discussed herewith is thoroughly documented with references to the literature of tissue culture, but as nearly every paper on the subject bears in some way on the present views, only a few have been selected for definite mention. These have been chosen because of their specific application to the points under discussion. See especially the bibliography of Lewis and Lewis (1924) and the *Arch. Exper. Zellforsch,* ed. Erdmann, R. The writer has been given much assistance in assembling the bibliographic data by Dr. J. N. Gowanloch, but is more especially indebted to him for valued criticisms and suggestions.

FACTORS IN TISSUE CULTURE.

An abundant literature, as above noted, has established the fact that animal and plant tissues may be readily cultured when removed from the organism of which they form a part. Such explants, if placed in a suitable medium, will perform their natural functions including those of reproduction. The following brief consideration of pertinent factors will serve to establish the basic data necessary for the purposes of the present discussion.

1. *Cellular immortality:* The small confines of a hanging drop has been sufficient for much tissue culture work, but due to the rapid loss of nutrient value and the accumulation of toxic wastes, such are necessarily limited to short periods unless frequent recourse is made to sub-culturing. With careful renewal of media, explanted cells may be cultured indefinitely and give every indication of being as capable of perpetuating their kind as

any natural organism. Tissue strains from chickens have already reached ages far exceeding the life span of the deriving animal type and show no abatement in vigor. Carrel (1912), Ebeling (1913 and 1922), Baker and Carrel (1926a and b).

2. *Media:* A great variety of solutions is capable of supporting tissue growth and there is a large range of permissible variation in tonicity, pH value, and other important cytologic factors, Lewis and Lewis (1924). As media are usually directly or indirectly imitative of plasma, with or without the addition of nutrient substances, they necessarily tend also to approximate dilute ocean water. It has been shown that various dilutions of sea water itself make satisfactory fluids for cultures in vitro, Lewis (1916), Dederer (1921).

3. *Influence of environment:* Many papers discussing cultures of extirpated cells make mention of changes induced by modifications of the culture media. Other environmental influences are responsible for appropriate modifications in morphology or behavior. Which of these can be considered as genetic, and which the direct impress of environment on each individual cell, is still largely controversial, Uhlenhuth (1915 and 1916). Experiments involving the use of X-rays, however, suggest the former, as might be expected, Strangeways (1924).

4. *Limits of space:* One of the effects of small stagnant bodies of media is outlined under "Cellular immortality." Another is that of excessive bacterial infection. Consequently, tissue culture is usually carried on under sterile conditions in order to prevent the establishment of destructive bacterial colonies. Many kinds of bacteria are preeminently suited to rapid proliferation in a nutrient hanging drop, whereas the explanted cells have no such natural advantage. The same condition is presented in the maintenance of any aquatic organism in a laboratory jar. In any such case the difficulty regarding offensive bacteria is directly proportional to crowding and its attendant effects. It may be readily demonstrated that this is, in part, a function of the quantity of fluid in relation to the organic bulk. It is, therefore, all the more remarkable that numerous students have been able to grow both cells and bacteria in a common drop. Furthermore, they have studied the ensuing interactions and in some cases phagocytosis was observed to be of apparent nutrient value, Johnson (1915), Smyth (1916a and c). The presence of bacteria also apparently acts as a growth-promoting stimulus. Smyth (1916b) wrote of his work, "These results seem to indicate that many bacteria may be utilized by tissue cells as food for growth, or may contain a substance or substances stimulating cell growth or multiplication."

If the preceding four items are considered with mutual reference it becomes apparent that there is no evident reason to prevent the establishment of a culture combining the factors that have already been established separately by a large number of independent investigators. Such a culture would require only some fluid medium of natural occurrence, such as dilute sea water, of sufficient bulk and renewal to prevent an excessive bacterial growth. In other words, the limitations of the tiny bodies of media ordinarily employed, with their consequent favoring of bacteria, must be circumvented. Suggested methods include the following: The fluid medium, in proportion to the organic matter, must be of such a quantity that bacteria have not enough dispersed food to form a dangerously rich culture. This must be below some critical value. In this connection hints are to be found in the maintenance of standing water aquaria in which the food substances must remain below a certain point for similar reasons. An alternative would be a circulation of the medium which might be worked out on a modification of the technique of Burrows (1912). These concepts are obviously derived directly from aquarium practice and it should now be apparent that there is no trenchant difference between the fundamentals of tissue culture and any form of animal or plant husbandry. In all, the

desired organisms are retained in more or less restricted confines and must be protected from enemies, fed, and freed of their own toxic wastes. The smaller the environment in relation to the number of organisms the greater the difficulty in maintaining a persistent culture. In the case under consideration food might have to be introduced manually from time to time in order to avoid nutrient fluids so especially beneficial to bacterial increase.

Experiments such as outlined above are now under way but it has been deemed best to place the above facts and the hypothesis they support on record at this time for the following reasons: The separate elements of the experiment have already been established independently by others. The only service the proposed experiments would perform would be to join certain separate factors. To be of real value it would have to be an operation involving a long period. Negative results might only be an indication of lack of skill on the part of the operator, or some technical difficulty. Others, better equipped than the writer, may be able to contribute more readily to the establishment of proper technique. Some of the problems encountered and the difficulties involved in the experiments thus far performed are discussed subsequently.

Inferences Based on Tissue Culture.

Since all of the conditions discussed are met with in a state of nature, there is good reason to consider the possibility of cultures of this sort arising spontaneously. The natural occurrence of the specific requirements may be considered for comparison with corresponding factors in laboratory cultures.

1. *Sources of materials:* Any event which causes an animal or plant to part with living cells supplies potential material. Such would include destruction by predacious forms, fighting, accidents, physical malfunctioning, such as hemorrhage, and in certain cases normal functioning. Without going into explicit detail it is sufficiently evident that wherever there is any form of life, parts are being continually separated from individuals in relatively immense quantities. Human foetal membranes and menstrual mucosa were successfully cultured by Konrad (1928). Amoebocytes and other cellular elements are normally shed in a living state by many organisms, if not by all.

2. *Media:* Any natural water that is suitable as a culture medium is potentially available for natural explants. For example, brackish sea water has been shown experimentally to be such and is frequently closely similar to plasma. The possibilities would thus vary, both specifically and geographically.

3. *Influences of environment:* Other environmental factors would act favorably or not, according to the nature of the experiment; *e.g.* explants from poikilothermal animals would have little likelihood of being destroyed by the temperature of the environment but homoiothermal ones might require water of approximately body temperature. That explanted cells, even of homoiothermal forms, have a truly remarkable resistance to unfavorable conditions of a most extreme kind has been repeatedly demonstrated. See, for example, Rous and Jones (1916), Nageotte (1927) and Morosow (1928a and b).

4. *Limits of space:* In this regard, the natural culture would be much more advantageously situated than the laboratory drop. It is the same kind of difference that obtains between a small aquarium and a body of open water. In a state of nature the food is automatically supplied and toxic wastes are either washed away or rendered innocuous.

5. *Enemies:* Instead of being protected from enemies, natural explants would have to take the chance of any organism invading a new environment. Other things being equal, the dangers from bacteria would be vastly less than in a laboratory culture. This limits successful establishment to rea-

sonably "clean" environments and rules out those that are characterized by a large amount of decomposition. In some environments, consisting of long-standing organic equilibria, bacteria seem to be at a disadvantage because of the presence of a lysisime or bacteriophage. Such conditions not infrequently may be found in standing aquaria, Breder (1931). In this connection it is notable that the cells in their original locations within an animal body are not in a sterile environment. The sterility of a culture medium is chiefly a concession for the enforced disadvantages of the cramped quarters, comparable to the omission of the natural enemies of fishes in an aquarium. Considering such explants as invading organisms it should be borne in mind that they would usually be reinforced continually by similar cells from the original source. An example would be the case of a predacious animal feeding chiefly on a single food animal (a type of specificity of frequent natural occurrence) with the continued escape of its tissues on being crushed. Since embryological material is generally more suitable for tissue culture, it may be noted that gravid females falling prey or the robbing of nests would abundantly supply much material. A hypothetical case is given below for illustrative purposes.

The arena might be a newly formed tropical swamp where the sea has inundated a low fresh water bog, depressing the quantity of its micro-fauna (protozoans, bacteria, et cetera), and in which the ocean water fauna (somewhat dilute) has not yet thoroughly established itself, but in which currents have washed various areas clean. Crocodiles could be feeding rapaciously on small animals, water fowl, et cetera, and so release—in some cases as single cells—the various constituents of the blood and in a less quantity epithelium, foetal material, et cetera.

It is experimentally demonstrable that an abundance of such explants are actually being continually released wherever there is a struggle for existence, that suitable natural media are clearly of worldwide occurrence and that the potency of the chief primary enemies, bacteria, is generally inversely proportional to the size of the fluid environment. Since the first appearance of the earliest metazoans the proper constellation of factors could easily have occurred many times. With this as a working hypothesis, we may consider some of the more apparent philosophical implications. Either such explants are capable of continued life, as is indicated by long-time cultures, or they are not. If the latter is true they would all eventually die off, but in the interim would exist to confound protozoan systematics. Attention need hardly be called to the striking similarity in morphology and behavior between free metazoan cells and protozoa, *e.g.* *Amoeba* and phagocytes, Hogue (1922), or ciliates and the singly freed cells of echinoderm eggs, Jenkinson (1909). Since numerous tissue culturists have shown that various environmental factors influence the morphology and behavior of their explants, natural cultures would certainly show comparable changes and probably bear little resemblance to their deriving tissues.

It has been shown that protozoans do not necessarily require fertilization to maintain vitality in subsequent generations. In eleven thousand generations of *Paramecium,* Woodruff (1926) found perfectly normal individuals produced by binary fission, but he did find some activity within single individuals involving a rearrangement of nuclear material for which he created the term endomixis, Woodruff and Erdmann (1914), Woodruff (1925), Calkins (1926). Behavior of nuclei of cultured tissues strangely resembling endomixis has been repeatedly observed, Holmes (1914), Macklin (1916) and Dederer (1921). There is no reason to believe that there is any fundamental functional difference between such acts and the observations of Woodruff. With these facts at hand it is quite conceivable that explanted cells under proper environmental stimulus might even show other than binary fission. It would be interesting to know whether the nuclear adjustments in tissue cultures are stimulated by explanting, or

whether they represent normal activity. If the latter is true the connection of the possible loss of such activity with senility and the relatively poor behavior of adult material in vitro is suggested. It is to be noted in this connection that while explanted cells usually retain their individual cell characteristics they frequently show dedifferentiation pointing to a less specialized and somewhat embryonic condition, Lewis (1920), Fisher (1922). These effects are clearly involved in the lack of endocrine and other control. For example, there is evidence that plasma from old animals checks growth in vitro, Baker and Carrel (1926 a and b).

Contemplating the other alternative, that natural explants are capable of survival, there is nothing remaining to separate them from the protozoa, and as they have been experimentally shown to be reactive to environmental stimulus there is no reason to suppose that they lack the evolutionary possibilities attributed to other forms of life. With such an assumption we should have "protozoa" derived directly from metazoa but charged with specific potentialities of various sorts dependent on the functions of their immediate ancestors as parts of a metazoan unit. Geneticists may object to this as a possibility on a basis of theory involving the continuity of germ plasma as distinct from somatic structure. However, there appears to be no theory or genetical experiments that have any bearing on the matter and the distinction referred to cannot be extended to the present case, for with self-sustaining and reproducing cells entirely free from the originating metazoan unit they at once may be considered germinal and somatic in every sense that a conventional protozoan is so considered.

A view set forth by Marchand (1935) would seem somewhat to approach the present in that it attempts to derive solitary coelenterates from colonial forms. Actually this view has little in common with the present, since the argument runs to the effect that evolution from "single cells" to complex forms was through colonial forms which subsequently separated, rather than direct. Be that as it may, the present hypothesis concerns itself solely with the ability of organic fragments to survive and to evolve.

The consequences of the present view would be to upset the unity of phylogeny and if shown tenable would introduce complications in a number of disciplines. Just how far this might be carried is of course very uncertain, but it could conceivably account for the lack of convergence in geologic time of certain phyla. It is difficult to imagine the tracing of a major phylogenetic tree with such a condition obtaining. As all the conventional phyla extend a great distance in geologic time it would follow that an origin from such a source could have occurred only in the remote past, except possibly considering the protozoa as a mixed phylum. This would tend to discourage the entire thought, were it not for the fact that there are a large number of organisms that have no convincingly evident affinities and have been buffeted about in a vain effort to find a place for them, as is witnessed by any zoological text book with its numerous "appendices" or "incertae sedis." For example, Parker and Haswell (1910) list eleven phyla and to these are added seven "appendix" forms. Without attempting to press the speculation too far it is clear that this condition obviates any necessity to allocate such an origin of forms to any particular geologic period.

A consideration of the general geographical requirements of derivation might be somewhat as follows: *Tropical,* homoiothermal vertebrates; *any climate,* poikilothermal vertebrates, invertebrates, plants.

Coupled with this list must go such factors of environment as suitable chemical quality of the water, a proper osmotic pressure, a sufficient freedom from enemies, et cetera (*i.e.* a sufficiently suitable environment).

As it has been shown that a variety of transplants is possible from one organism to another, for example blood transfusions, glandular transplants, plant and animal grafting, et cetera, on the basis of the preceding, occasionally natural transplants might well originate. The remarkable production

of complex plant monsters, Winkler (1914), and the composite *Hydras* of Issayev (1924), both show the ability of very different cells to live side by side. If recent explants are ingested or lodged in surface wounds the possibility of their survival arises. Certain carcinoma cells similar to their associates except in growth rate come to mind, including even the possibility of self-infection. It is noteworthy that malignant growths are most common at first near the surface or in the alimentary or other tract open to the exterior. Thus, a return cycle further complicating conditions would have bearing on a large number of academic and practical matters. At least it is certain the symbiotic relationships must have arisen in some such accidental manner. *Hydra viridis, Convoluta roscoffensis*, the lichens, or even man and his intestinal flora may serve as examples of various kinds of such associations. Buchsbaum and Buchsbaum (1934) produced what they considered an artificial symbiosis between tissue culture cells and the algae, *Chlorella*.

Passing beyond the limits of the indicated inferences of this hypothesis, we might even imagine bacteria to be mitochondria released in a similar manner. This would be inverse to the idea set forth by various students, most recently Wallin (1927), which view is objected to by Cowdry (1924). Viruses might be thought of as also being involved and derived from the fluids of ruptured cells. Schultz (1930) gives a general view of the behavior of viruses very suggestive in this connection. See also the discussion by Riddle (1936). It is recognized that the above is pure speculation and it is mentioned merely as indicative of the lines of thought engendered by a consideration of certain facts in the technique of tissue culture.

DIFFICULTIES OF EXPERIMENTAL PROCEDURE.

The experimental establishment of explanted tissues in relatively "wild" environments would place the entire suggestion on a relatively firm foundation. As previously noted there are both experimental, and, in the case of the writer, personal difficulties involved. Nevertheless, a considerable amount of experimentation was undertaken. For very substantial aid in this the writer is indebted to Dr. R. F. Nigrelli who labored with most of the actual physical material.

The following discussion of the results of this work is introduced chiefly to point out that in addition to ordinary experimental difficulties there are likewise theoretical obstacles to the establishment or destruction of the present hypothesis by experimental means. The discussion of certain experiments may serve to demonstrate the point.

The leucocytes of invertebrates were thought of as likely material for such experimentation. For example, those of the common oyster normally invade the mantle cavity and are frequently voided into the surrounding water, especially under slightly suffocating conditions, Orton (1924), Young (1928). This phenomenon, diapedeses, is apparently common to a variety of animals. Leucocytes so voided by the American species, *Ostrea virginica*, were found to live for as long as six days in a laboratory dish with no attention whatsoever, Breder and Nigrelli (1933), while those of the European oyster, *O. edulis*, lived for Orton up to four days. Such, then, would seem to be ideal material.

However, it so happens that *O. virginica* is infested with amoebic parasites (or commensals?), *Vahlkampfia calkinsi*, or *V. patuxent* or both. These are usually found in the intestinal tract, are voided with the faeces, and bear a strong superficial resemblance to the leucocytes. The latter likewise invade the intestinal tract in the course of their functional activity. The describer of these parasites, Hogue (1915, 1921 and 1922), was only able to distinguish them from the leucocytes after fixation, when with suitable staining the nuclear material was found to be differently arranged. Breder

and Nigrelli (1933) found in their dishes that in addition to parasites voided in the faeces, and leucocytes voided from the gill chamber, they also had a free living *Amoeba* of the *limax* type that normally lives on the exterior of the shell. This latter form caused no confusion, however. In agreement with Hogue they found (unpublished) that pure cultures of leucocytes withdrawn from the heart would not survive on agar plates for any great length of time, but that the parasites from the intestine could be so cultured. Thus it follows that the differentiation of leucocytes from parasites is dependent on (1) arrangement of nuclear material, for which the material must be killed and stained, and (2) ability to grow on agar plates.

Leucocytes from the heart will not grow on plates but material from the intestine will. Both parasites and leucocytes (as based on stained material) are found there, but on old agar plates only the "parasite" type of nucleus is found. It seems to the writer that there is just an even chance that these "parasites" may be one phase of the normal oyster leucocyte, especially since they always seem to be present. If they could be shown to be a phase or type of leucocyte occurring only in the gut, which has the possibility of exterior survival, this could be used for considerable support of the hypothesis. As it stands—parasite, commensal or leucocyte—it is clear that any point of view can be argued and experiments may prove one or the other, depending on the experimenter's bias, with no present hope of experimentally further separating the material.

Giving this line up, earthworms were examined, since they void amoeboid cells with their casts. Without going into details it may be stated that earthworms also harbor amoeboid parasites and a similar block to this line checked an experiment that seemingly held promise and made us wonder if all commensal or innocuous amoebic parasites were simply transformed leucocytes.

The application of micro-dissection to the problem involves a further philosophical consideration but points the way to the types of material that may hold some hope for experimental verification. If certain types of animals are disassociated the pieces will reunite to re-form the originals. Sponges, perhaps, represent the best known case of this sort. *Hydra* will also show this phenomenon, Papenfuss (1934), but under certain conditions will not. The fate of the individual cells under such conditions is not yet certain. Obviously, freed cells that reunite to construct organisms cannot be expected to be of much value for this kind of experiment. On the other hand highly specialized and protected cellular elements could hardly be expected to survive without the complex of conditions under which they normally exist. Consequently the type of tissue that presumably must be sought after in this connection is something sufficiently unspecialized as to be able to survive in a new environment and still without the ability to reconstruct an individual animal with its fellows. In this connection it may be pointed out that it is sometimes surprising to note what ordinarily well protected tissues may do in the way of survival under exposed conditions. Nigrelli and Breder (1935) describe a prolapsed fish intestine, which while fed with body juices was exposed to the ordinary standing water of an aquarium. This pendant piece proliferated for several months and was finally killed for study.

CONCLUSION.

The hypothesis that animal and plant cells when dislodged from their original locations *in situ* by natural causes may continue living independently as distinct organic units rests on a large number of concrete experimental demonstrations by independent investigators. These contributions were all made with reference to special and distinctly diverse problems not in the least connected with the present integrated interpretation of them.

That they are adequate and pertinent to this hypothesis can be sustained by reference to the total literature of tissue culture and the absence therein of any contrary findings. Experimental verification, however, must wait on the development of a more satisfactory approach than is now available. The author, at least, has thus far been unable to devise a practicable experiment, the results of which can be interpreted in but one way. The continued presence of this duality of possible interpretation stands as an impediment to experimental analysis of the problem. The conception of a critical experiment must be realized before further progress can be expected. That tissue culture has been possible and that a large variety of cells have been grown and have perpetuated themselves for long periods in a considerable variety of environments may be taken as good presumptive evidence in favor of this hypothesis.

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11.

Preliminary Note on the Nature of the Electrical Discharges of the Electric Eel, *Electrophorus electricus* (Linnaeus).

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&

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(Text-figure 1).

Although the Electric Eel has been known to science since 1729 and has been the subject of much speculation and an enormous literature in respect to the nature of the electrical phenomena exhibited, there is still a considerable discrepancy between the voltages observed by different investigators and a great deal yet to be learned about the nature of the generation and discharge of these voltages. Since the development of the Cathode Ray Oscillograph, we think that more accurate observations may be made than any heretofore, and present this short report of our findings to date.

Preliminary observations into the voltage developed were made by means of a device of resistances and neon pips designed and built for us by Mr. H. M. Ferree of the General Electric Vapor Lamp Company. This indicated the voltages in steps ranging from 85 to 150; 150-170; 170-300; 200-450 and 450-600. The eels used in this preliminary investigation varied in size from 11½ inches to 7 feet 10 inches and readings were taken both in and out of water. In no single instance was a voltage beyond the 170-300 range recorded. This is not in accord with voltages reported by Eilenfeld.[1] Some of the fish were tested immediately upon arrival and some after they had been in aquaria for several years, being fed, during that time, on a variety of living fishes which necessitated the continued use of electrical discharges on the part of the eel if it were to eat. Table I gives the respective sizes of the various eels tested.

Small eels were found to be more suitable for investigations with the oscillograph, which was a Radio Corporation of America Cathode Ray oscillograph type T M V-122-B. In the most satisfactory observations the eel under test was removed from the water, dried, and laid in an insulating trough two inches wide, in which were set transverse tinned copper wires one inch apart. By means of dial switches any two of these wires could be connected to one pair of deflecting plates of the oscillograph. With the timing circuit connected to the other pair of deflecting plates the variation of the voltage in time could be observed.

Two types of discharge were clearly distinguished.[2] In each type the voltage between two points on the eel rose to a maximum and returned to zero. The anterior part of the eel was always positive with respect to the posterior *and no reversal of voltage* was observed. The curve showing the variation of voltage with time appeared symmetrical and the shape suggested a Gaussian errors curve. The duration of one discharge was of the

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[1] EILENFELD, Walter: Ueber den Reflexschlag von *Gymnotus electricus* nach Untersuchungen mit dem Oszillographen Beiträge zur Physiologie, Berlin, 1927, Band 3, pp. 195-198.
[2] This is in accord with those reported by Eilenfeld.

order of 10⁻³ second. The two types of discharge differed strikingly in potential variation along the eel and in the maximum voltage attained. Observations on both types made on an eel 11.5 inches long with 55 cc. displacement in water are shown on the figure. The abscissa shows distances measured along the eel from head to tail. The difference in ordinate between any two points shows the peak voltage developed between the points on the eel corresponding to the associated values of the abscissa. It will be noticed that in the principal discharge the potential is uniform over the anterior two inches and the posterior two inches of the eel. In the less vigorous or secondary discharge the potential is uniform over the anterior four inches and the posterior two inches of the eel. The origins of the Large Electric Organs and Hunter's Organs were two inches posterior to the snout and the origins of the Bundles of Sachs were about No. 7 on the figure.

The peak voltage observed in either type of discharge between any two points was not repeated uniformly. In successive discharges of the principal type deviations from the mean of 25 per cent. were observed. The voltages developed also diminished as the eel was kept a longer time out of water. The contrast between the two types of discharge, as shown in the figure, is probably exaggerated by this latter cause, the observations on the secondary discharge having been commenced after the observations on the primary discharge were completed, and indeed after the maximum voltage of the primary discharge had been observed to fall from its initial value around 200 volts to about 135 volts.

In this respect it might be as well to note that there is a wide variation in the rate of fatigue between different animals and the same animal in different conditions. This has been observed but not recorded by one of us over several years' work with many eels of all sizes.

Observations of another eel of about the same size showed a principal discharge of about 200 volts accompanied by a secondary discharge of about 20 volts, and observations of a third eel 15½ inches long showed a principal discharge of about 145 volts accompanied by a secondary discharge of about 30 volts.

Another difference observed between the principal and secondary discharges was that while the secondary discharges follow one another apparently at random intervals of time, the principal discharges commonly occur in pairs with a rather regular interval which is several times the duration of one discharge.

Some observations suggested a third type of discharge with a peak voltage around one volt, but the disturbances to which the oscillograph is subject with the high amplification required to show such a discharge render its existence uncertain, as yet.

No satisfactory measurements were made of the power developed in the discharges. Some rough observations on an eel about 12 inches long give a value of the order of 3 watts for the power developed externally at the peak of the principal discharge when the eel is in the water to which it is accustomed.

To determine whether the change in potential begins simultaneously at all points along the length of the eel or whether there is a progressive potential pulse from head to tail, the timing circuit of the oscillograph was cut off and one plate of each deflecting pair was connected to one point on the eel somewhat behind the middle and the other plates were connected near the head and tail respectively. If there were no time lag, the trace on the oscillograph screen would be a straight line, since the two voltages giving rise to the vertical and horizontal displacements of the beam of cathode rays would have a ratio constant in time. The trace observed was, on the contrary, a narrow loop, roughly elliptical. This seems to indicate that the potential pulse is propagated along the eel in a time of the same order as, or less than, the duration of the pulse between two points. Since
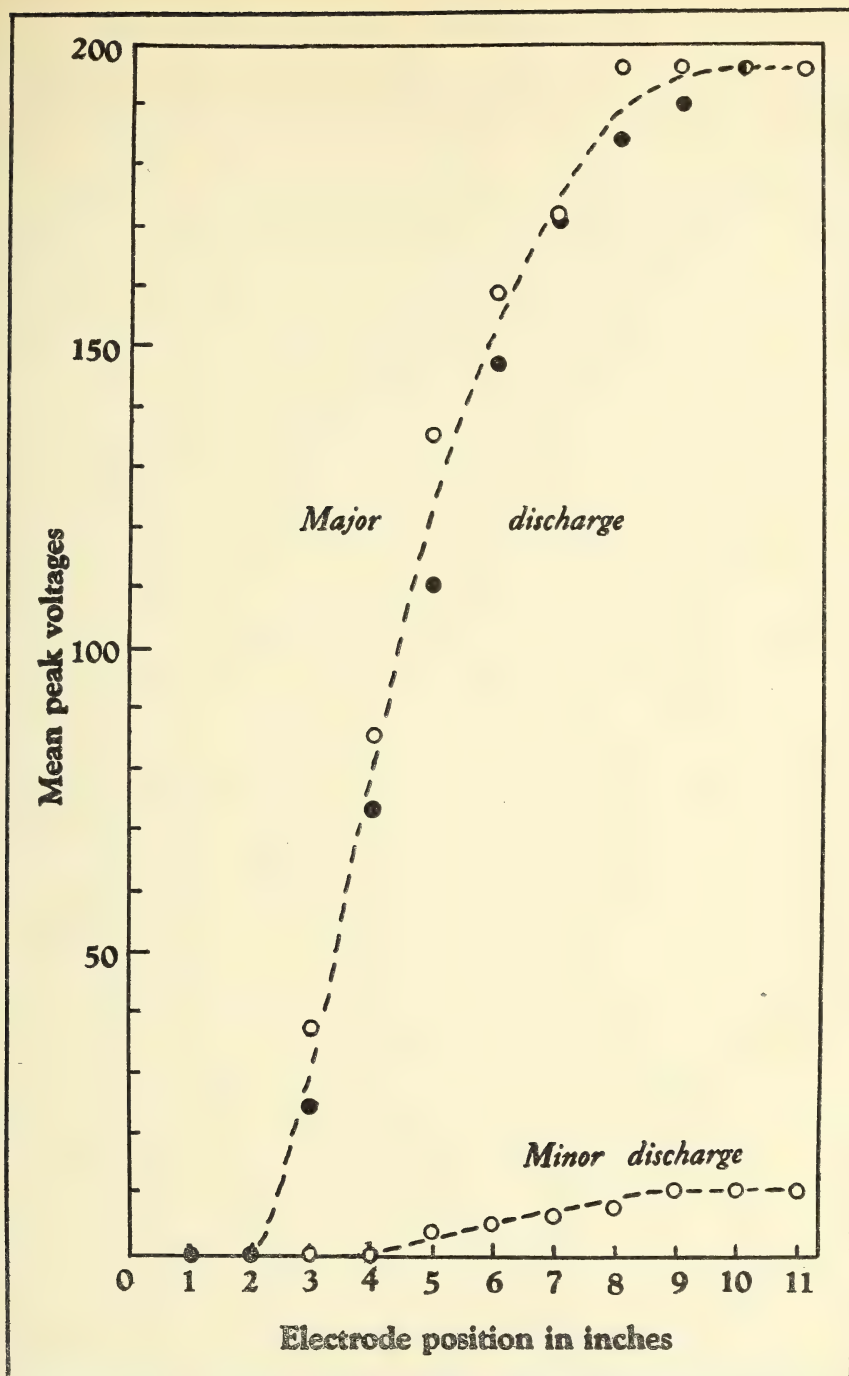
Text-figure 1.

Graph showing mean peak voltages at 1-inch intervals on Eel No. 2. The open circles on the major discharge curve represent voltage readings taken from head to tail; the black dots represent readings taken in the reverse order. In the minor discharge, no differences were observed in readings from either direction.

the eel was about one foot in length, the speed of the pulse would appear to be of the order of 1,000 feet per second. Such a speed is higher than those commonly found in the propagation of electrical impulses along nerves.

TABLE I.

Size of Eels on which measurements were made.

3	eels 7	feet	long		
3	" 7	"	3	inches	in water only.
1	" 7	"	9	"	
1	" 7	"	10	"	
1	" 3	"	4	"	both in and out of water.
1	" 3	"	1	"	
1	" 2	"	10	"	
1	" 1	"	3½	"	
2	"		11½	"	

TABLE II.

Eel No. 2. Length 11½ inches.
Mean peak voltage of major discharge.

TEST No. 1			TEST No. 2			
Electrode A	Electrode B	Voltage	Electrode B	Electrode A	Voltage	Voltage reckoned from 0
0	2	x	11	0	196	0
	3	37		1	196	0
	4	86		2	196	0
	5	135		3	172	24
	6	159		4	122	74
	7	172		5	86	110
	8	196		6	49	147
	9	196		7	25	171
	10	196		8	12	184
	11	196		9	6	190
				10	x	196

TEST No. 3					TEST No. 4 Mean peak voltage of minor discharge			
Electrode A	Electrode B	Observed voltage	Corrected voltage†	Voltage from curve	Electrode A	Electrode B	Voltage	Voltage reckoned from 0
0	11	135	196	196	0	11	10.5	0
0	10	135	196	196	1		10.5	0
1	10	135	196	196	2		10.5	0
1	9	135	196	196	3		10.5	0
2	9	135	196	196	4		10.5	0
2	8	122	177	189	5		6.6	3.9
3	8	110	160	159	6		5.3	5.2
3	7	98	142	145	7		4.0	6.5
3	6	74	107	125	8		2.7	7.8
4	6	49	71	73	9		x	10.5
4	5	37	54	42				

†—Observed voltage x $\dfrac{196}{135}$ to correct for fatigue.

x—voltage too small to read.

Tests were made consecutively with five minute rest intervals between each.

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS

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CONTENTS

12.

The Morphology, Cytology and Life-history of *Oodinium ocellatum* Brown, a Dinoflagellate Parasite on Marine Fishes[1].

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(Plates I-IX; Text-figures 1-5).

CONTENTS.

INTRODUCTION.

Parasitic dinoflagellates have been known for many years, but it is only recently that a species has been described from fishes. Brown (1931), in a preliminary note, reported a new species, *Oodinium ocellatum,* from the gills and skin of marine fishes, as the cause of a high mortality in the Aquarium of the Zoological Society of London. In a later paper (1934) she extended her observations, but added little concerning the morphology and life-history of the dinoflagellate.

According to Brown (1934), the parasite is found on marine fishes collected from the East and West Indies. In the New York Aquarium, however, the infection has been centered in fishes taken from Sandy Hook Bay and has spread to a few species from Key West, Florida. This is the first record of the parasite from North American waters. None of the East Indian forms present in the Aquarium were found infected.

A number of parasitic dinoflagellates have been described, and much of

the literature has been reviewed in detail in the excellent monograph by Chatton (1920). Kofoid and Swezy (1921) have pointed out the need for more thorough investigation of these organisms, since many details are lacking in the descriptions of their morphology and life-history. The recent occurrence of *Oodinium ocellatum* in large numbers in the New York Aquarium has afforded an opportunity for further investigation on this species.

The writer wishes to express his thanks to Professor R. P. Hall for the many valuable suggestions and criticisms offered in the preparation of this paper.

MATERIAL AND METHODS.

The parasites were removed for study from the gills of *Chilomycterus schoepfii* and *Spheroides maculatus,* which were dying as a result of the infection. Infected fish could be detected by their actions and also by a pink-tinted mucous secretion on the surface of the body. This pink color is due possibly to waste products of the parasites, much as "red water" is produced by free-swimming dinoflagellates (Meade, 1898; Kofoid and Swezy, 1921; Martin and Nelson, 1929).

Infected gills were fixed in 10% neutral formalin, Zenker's fluid, corrosive sublimate and Bouin's solution. The material was sectioned and after each fixative some sections were stained with Delafield's hematoxylin and others with iron-hematoxylin, eosin being used as counterstain in certain cases. Tissue fixed in Zenker's fluid was also stained with Mallory's triple stain; other material fixed in corrosive sublimate and stained with iron-hematoxylin was counterstained with Van Giesen's fuchsin-picric acid in an attempt to demonstrate fibrils in vegetative stages of the parasites. Most of the hematoxylin-eosin material was destained for the study of nuclear and cytoplasmic structures. In such cases, the rhizoid processes of the attached stages were always completely destained. To overcome this difficulty, a few of the sections were overstained; in this way the rhizoid processes which penetrate the gills were demonstrated.

Parasites showing organelle of attachment in various stages of protrusion were obtained by strongly shaking the gills and allowing the parasites to fall into Schaudinn's and Bouin's fluids. By this method many of the flagellates were fixed before this peculiar organelle could be completely retracted.

In order to obtain division stages a large number of the parasites were washed in sterile sea-water, distributed to several petri dishes, and then fixed at intervals.

The iodine-potassium method, such as employed by Hall and Nigrelli (1931), was used to demonstrate the presence of starch, and in attempts to determine the nature of the small cytoplasmic inclusions described as amyloid bodies by several investigators.

Living specimens were examined under the oil-immersion objective, and many details in the morphology and life-history were observed which would not have been evident in fixed and stained material. In order to check the observations made on mass cultures, single flagellates were isolated in sealed hanging drop preparations, and observed daily. In this way stages in the life-history were traced in pure line cultures.

Experimental infections were attempted in two cases, in one instance with the parasitic stage directly from the gills of an infected host, and in the second with dinospores grown in the laboratory in petri dishes. The results of these experiments are discussed later in the paper. The effects of various temperatures and different specific gravities of sea-water on development were also investigated. Cultures were kept at 12.5°C., 25°C., and

35°C. with the density kept constant at 1.028. In the density experiments, sea-water having an initial specific gravity of 1.028 was gradually evaporated to a density of 1.040. By dilution with normal sea-water, a range was obtained from 1.040 to 1.028. A second series was started with sea-water at a density of 1.028 and, by dilution with fresh water, the range was extended to 1.003. All density readings were taken at the standard temperature of 15°C.

LIFE-HISTORY OF *Oodinium ocellatum.*

The parasitic stage of *O. ocellatum* is a pear-shaped organism (Text-fig. 1, A-F; Pl. I, Fig. 1) attached to the gill filaments of marine fishes by means of fine rhizoids. When the organism attains a large size, this method
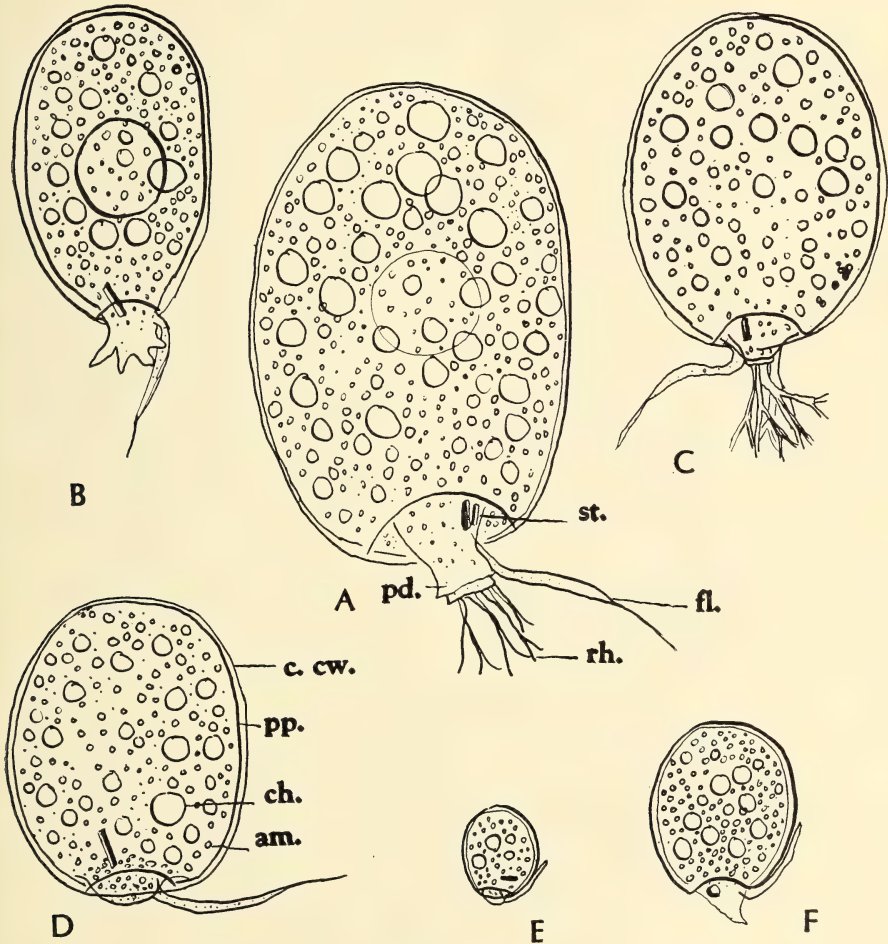
Text-figure 1.

A-F. Camera lucida drawings of the living parasite. x 950. Various stages and sizes of the parasitic form just after removal from the gills. *st.*, stigma-neuromotor complex; *pd.*, peduncle; *rh.*, rhizoids; *fl.*, flagellum; *c. cw.*, cellulose membrane; *pp.*, periplast; *ch.*, chromoplastids; *am.*, amyloid granules.

of attachment apparently becomes mechanically inadequate and the para-
site drops off the gills.   However, all the organisms, regardless of size, will
undergo division once they are removed from the gills. On settling to the
substratum, the dinoflagellate takes in water, possibly through the canal
present in the peduncle, and increases in volume by one-fourth or more of
the original size.   All of the organelles, including a broad "flagellum" pres-
ent in this region, are gradually retracted within the body of the parasite
and a cellulose cap is secreted to seal the original opening (Text-fig. 2, G;
Pl. I, Fig. 2).   When this process is completed, division is initiated.

The cytoplasm, at the pole diametrically opposite the region of the
peduncle, recedes from the cellulose covering (Text-fig. 2, H; Pl. I, Fig. 3).
This is the point at which the first fission will start; therefore, the first
division is longitudinal. Succeeding divisions are more or less regular, and
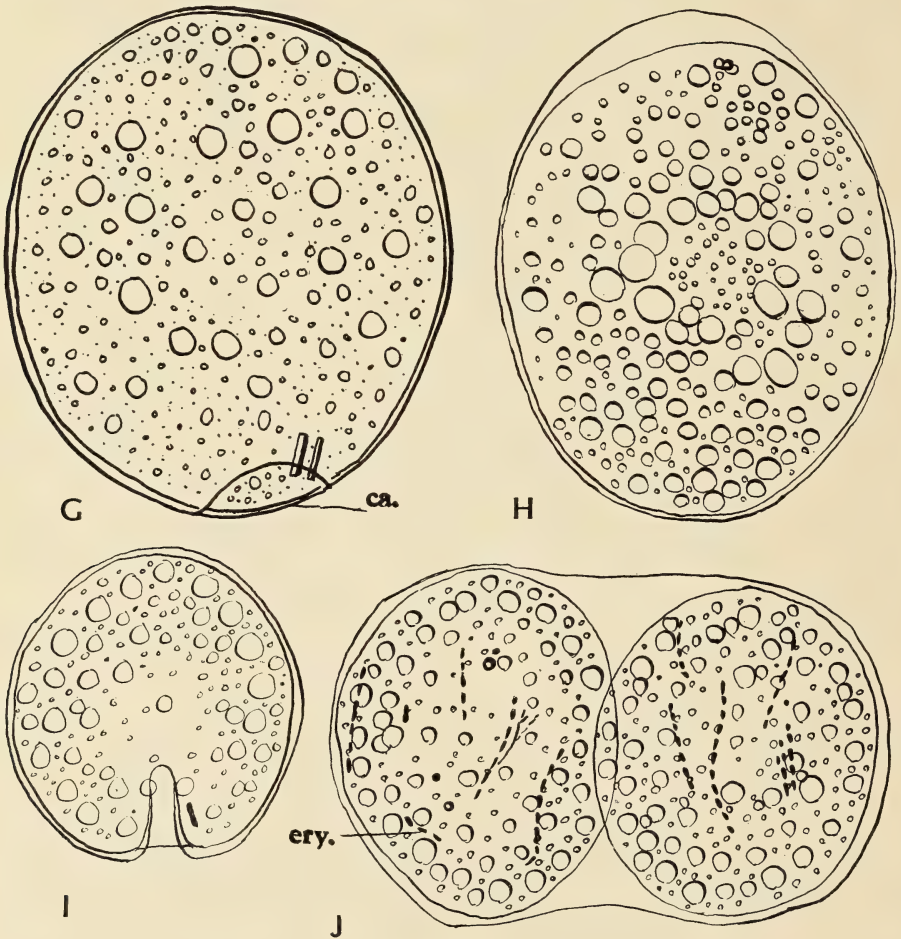
Text-figure 2.

Camera lucida drawings of the living parasite. x 950.   G.   After imbibition of
water a cellulose cap (*ca.*) is secreted. Note the two stigma-neuromotor complex.
H. Recession of the cell proper from the cellulose wall at the anterior end. Note
absence of both erythrosomes and stigma. I. Stage in the retraction of the polar
structures. J. End of the first division; *ery.*, erythrosomes.

at right angles to each other, giving rise to palmella stages of 2, 4, 8, 16, 32, 64, and 128 cells (Text-figs. 2, 3, 4, J-N; Pl. I, Figs. 4, 5). One more palmella division occurs to form 256 minute dinospores. These become flagellated, break through the cyst wall and for a short time are free-swimming naked dinospores but without girdle or sulcus (Text-fig. 5, R, S; Pl. I, Fig. 6). In many cases the dinospores emerge from the palmella before the final division is completed (Text-fig. 5, P, Q). The dinospore then settles to the bottom, secretes a new cellulose covering (Text-fig. 5, T; Pl. I, Fig. 7) and
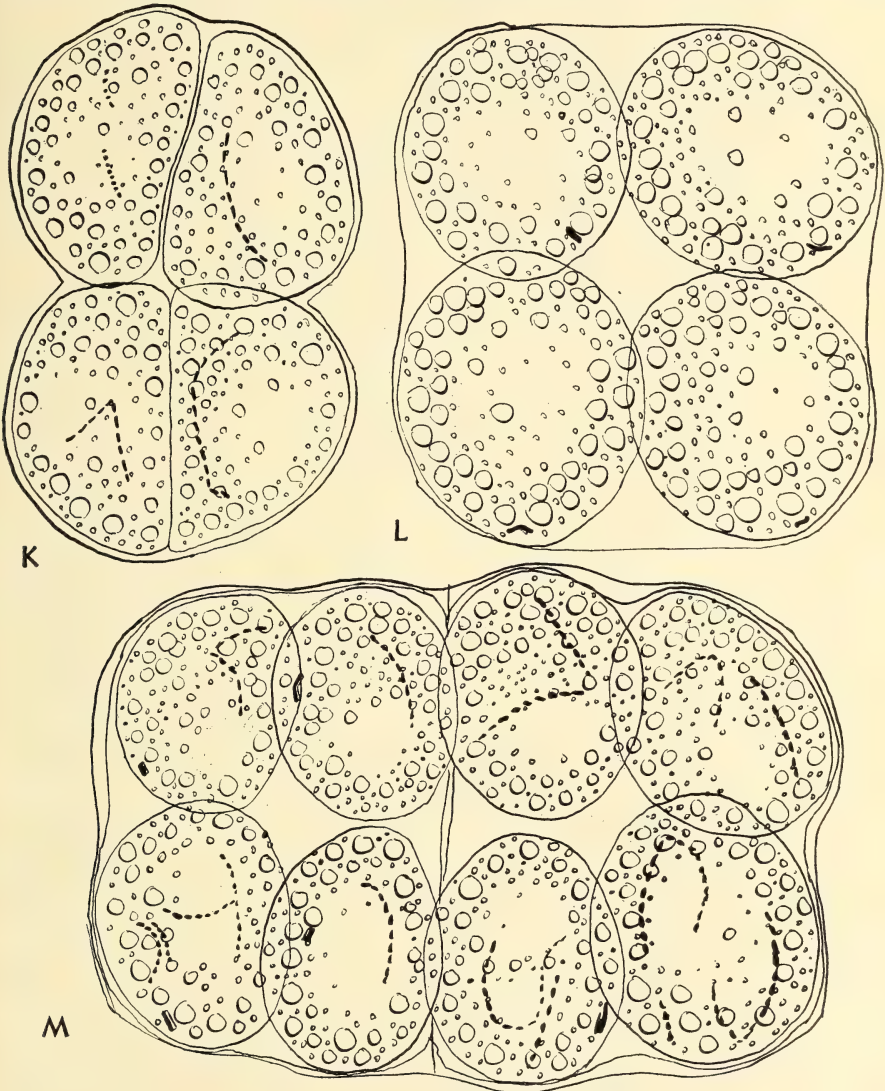
Text-figure 3.

Camera lucida drawings of the living parasite. x 950. K. Beginning of the 2nd cell division. L. End of the 2nd cell division; the erythrosomes have disappeared and in each cell a red bar may be seen but without the "desmose." M. 8 cell stage (flattened).

N

O
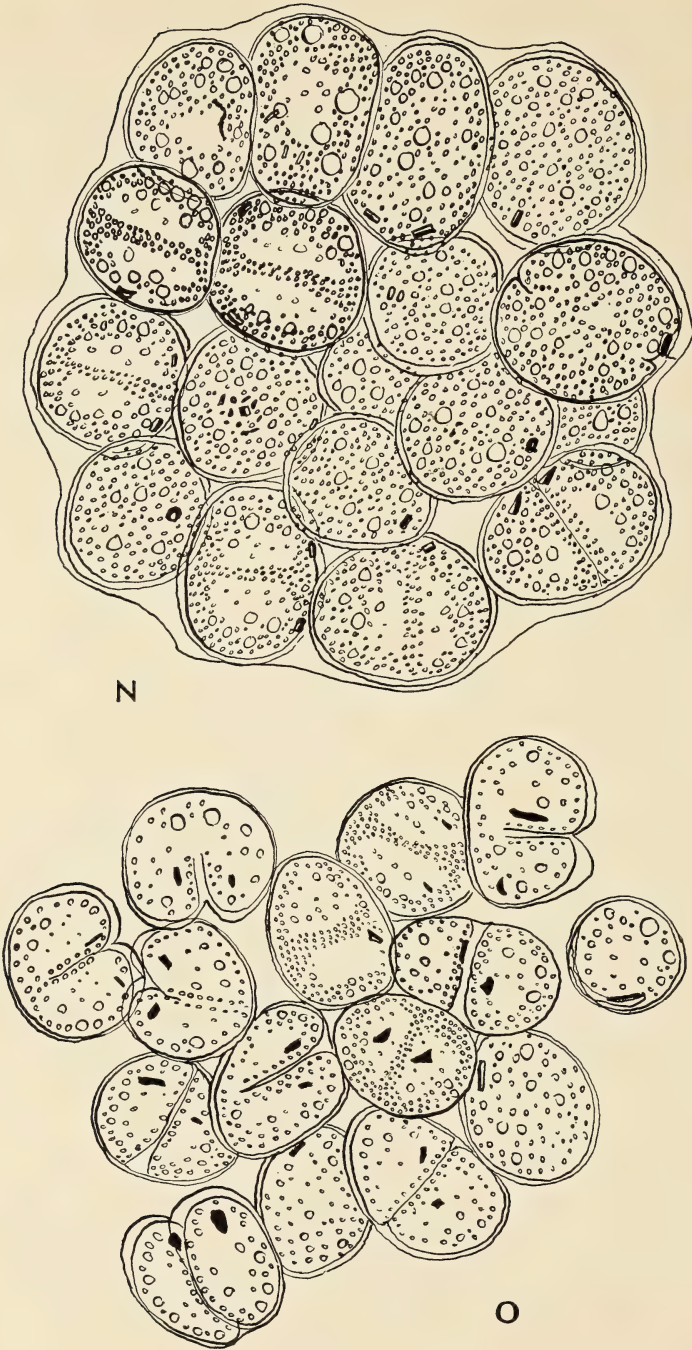
Text-figure 4.

Camera lucida drawings of the living parasite. x 950. N. Surface cells of a 32 cell stage, some of which show the alignment of the amyloid granules and the beginning of dinospore formation. O. Later stage in dinospore formation.

by certain cytoplasmic changes (Text-fig. 5, S-V; Pl. I, Figs. 8, 9) becomes transformed into a typical peridinian dinoflagellate (Text-fig. 5, W, X; Pl. I, Fig. 10). The latter possesses a well developed girdle with transverse flagellum and a short sulcus from which the longitudinal flagellum passes posteriorly. The metamorphosis of the peridinian into the parasitic stage could not be followed completely. However, evidence shows that the flagella are lost, while the sulcus widens out into a cone-shaped structure (Pl. IX, Fig. 75). From the latter, in all probability, arises the peduncle with its rhizoid processes.
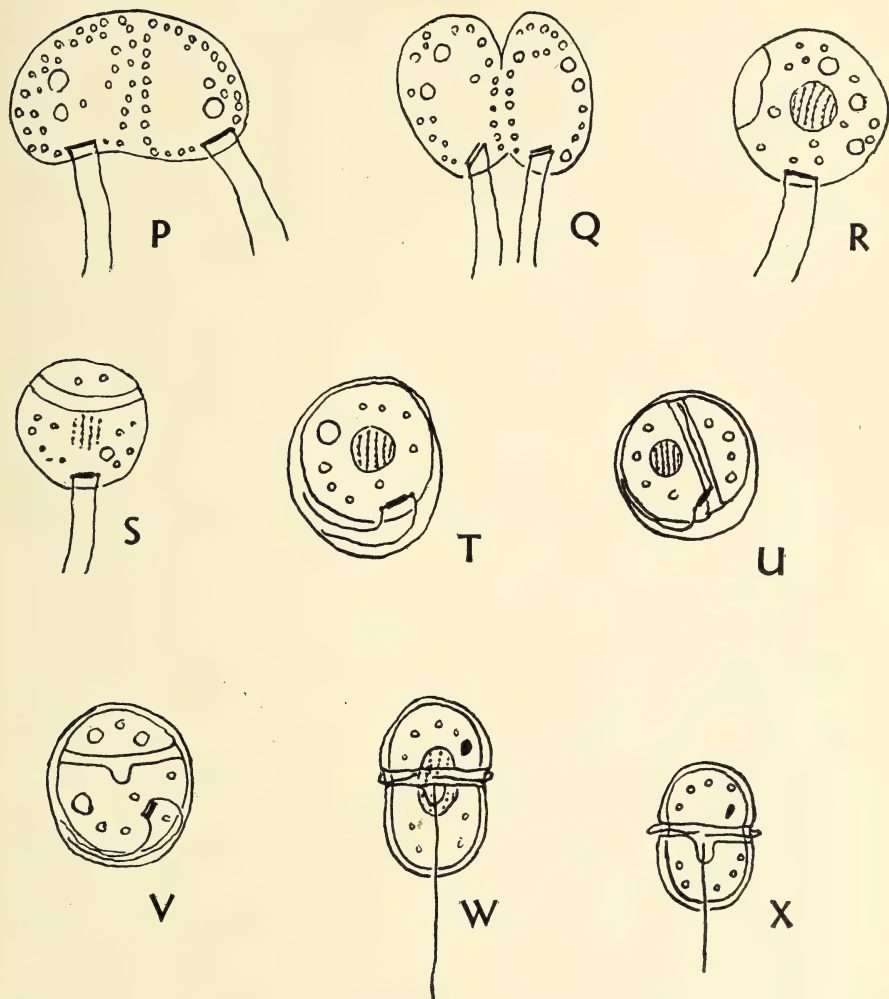
Text-figure 5.

Camera lucida drawings of the living parasite. x 950. P. "Binucleate" naked flagellate stage. Q. Beginning of the final dinospore division. Note the separation of the neuromotor apparatus and the bar-like stigma. R. Temporary free-living, naked dinospore. S. Form in which cytoplasmic differentiation has occurred. T. Rounding up and secretion of a new cellulose membrane. U. Note the orientation of the neuromotor apparatus. V. Cytoplasmic differentiation showing girdle and sulcus. The stigma-neuromotor complex has begun to move anteriorly. W, X. Typical free-swimming *Oodinium ocellatum.*

THE PARASITIC STAGE.

Oodinium ocellatum, (Pl. II, Figs. 11-24) as observed on the gill fila-
ments of the host, measures from 12.4 x 9.9 to 103.7 x 80.5 microns. Aver-
age measurements for one hundred specimens taken at random are 61.1
microns in length and 50.1 microns in width. On the other hand, when the
organisms round up after removal from the gills, they increase in volume
and may measure as much as 150 microns in diameter.

The parasite is surrounded by a firm transparent membrane which,
according to Brown (1934), gives a positive reaction for cellulose (Text-
fig. 1, c. cw.). The nucleus may be round or oval in shape and in many of
the living cells moniliform threads typical of the dinoflagellate nucleus are
apparent. The endosome which can be seen in fixed and stained specimens,
is not evident in the living material. The cytoplasm contains numerous
round chromoplastids (Text-fig. 1, ch.) of varying sizes, usually a pale
green in color (Pl. I) and giving the characteristic starch reaction with
iodine-potassium iodide solution. When large numbers of the parasites are
placed in a test-tube, the entire suspension will give the characteristic blue
color when treated with a few drops of the iodine solution. Also present
in the cytoplasm are numerous granules which show a purplish color on
treatment with iodine. Like Brown (1934), the writer interpreted these
as amyloid granules (Text-fig. 1, am.). ·

In fixed and stained specimens (Pl. II), the cytoplasm appears vacuo-
lated. In Mallory preparations (Pl. II, Figs. 21-24) there are a few red
small granules (microsomes?) which seem to be the same as those which
stain a light yellow with Van Giesen's method (Pl. II, Figs. 11-16). The
nature of these granules is not yet known; they were not observed in living
material. The cellulose wall is stained yellow with Van Giesen's, deep blue
with Mallory's and a brownish color with iron-hematoxylin. The chromo-
plastids are usually aggregated around the nucleus as a result of centri-
fuging. After iron-hematoxylin and eosin, these plastids show small bars
or dumb-bell structures which retain the hematoxylin; otherwise they are
stained homogenously with eosin. With iron-hematoxylin and Van Giesen's
stain (Pl. II, Figs. 14-16), the bars are similarly colored while the rest of
each plastid is stained yellow. With Mallory's, the chromplastids are red
or orange with bluish margins while the amyloid granules are light blue
(Pl. II, Figs. 21-24). The latter were not evident in other preparations.

One of the interesting features of this dinoflagellate is the organelle
of attachment present at the posterior part of the cell (Text-fig. 1, A-F;
Pl. I, Fig. 1; Pl. II; Pl. III, Figs. 25-27). This organelle, staining a light
blue with Mallory's and yellow with Van Giesen's, is composed of a trans-
parent base or peduncle (Text-fig. 1, pd.) which originates within the cyto-
plasm proper, passes through a large opening in the cellulose wall and ter-
minates in a pseudopodial tip, sometimes rhizopodial and sometimes lobo-
podial in appearance, depending on the state of retraction (Text-fig. 1, A-F).
It is by means of these "pseudopodia" or rhizoids (Text-fig. 1, rh.) that the
parasite anchors itself to the gill tissue of the host. When viewed under oil
immersion, the details of this region are clearly visible. In sectioned mate-
rial (Pl. II), the rhizoids appear as fine threads passing among the cells of
the gill tissues. After removal from the gills, these rhizoids become thicker
and more blunt in appearance but undifferentiated. In individuals in which
a certain amount of retraction has taken place the cytoplasm at the base
of the peduncle appears granular. In some cases this granular zone ex-
tends anteriorly almost to the region of the nucleus. In Mallory's triple
stain preparations this differentiated cytoplasm is stained blue, and in Van
Giesen's, yellow. At the base of the peduncle of the attached forms there
is a ring which stains red with Mallory's (Pl. II, Figs. 21-24) and yellow

with Van Giesen's (Pl. II, Figs. 11-16). The nature of this structure, which was not observed in the living flagellate, is unknown.

Besides this organelle, there is also present a peculiar broad ribbon-like "flagellum" (Text-fig. 1, fl.), which shows very slow sweeping movements. The "flagellum" is as hyaline in appearance as the rhizoid processes and, except for the movements in living specimens, it is difficult to distinguish this organelle from one of the rhizoids. In fixed and stained specimens removed from the gills both "flagellum" and rhizoid processes seem to arise from the granular cytoplasm at the posterior end of the cell. The "flagellum" apparently can be used in swimming. For example, several specimens were placed in one side of a petri dish and on the opposite side were placed pieces of non-infected gills taken from a killifish (*Fundulus heteroclitus*). Within ten minutes, a dozen young parasites were found attached to the gill filaments. Whether or not this stage of the dinoflagellate moves about on the gills within the branchial cavity of the host has not been determined. In one case the "flagellum" appeared continuous with the canal which extends from the peduncular region to a dense spherical mass of cytoplasm just posterior to the nucleus. The canal (Pl. II, Fig. 11; Pl. III, Fig. 27) is hyaline in appearance and takes a blue color with Mallory's triple stain. In specimens stained with iron-hematoxylin or Delafield's alone, it appears as a colorless structure, while in those counterstained with eosin, the canal takes on a pink tint. Such a canal was reported by Brown (1934), who likewise was unable to determine the exact relationships of the structure in either living or fixed and stained preparations. However, she also described a club-shaped vacuole (vesicle) connected with the canal in the peduncular region. In the present material no such vacuole was observed. The stigma (Text-fig. 1, st.), characteristic of *O. ocellatum,* is usually present in the peduncular region of the parasite and lateral in position. This organelle is composed of a broad red and a thin black pigment bar, between which there is a clear refractile area. Occasionally, there may be two such stigmas (Text-fig. 2, G).

Palmella Stages.

From two to five minutes after the parasites have been removed from the gill filaments, the rhizoids and the "flagellum" are gradually retracted. During the process of retraction, the organism shows a distinct increase in size, probably caused by imbibition of water, since brownian movement of cytoplasmic granules, not previously noticeable, becomes quite evident. After retraction is completed, the cell begins to secrete a layer of cellulose to close the gap (Text-fig. 2, G; Pl. I, Fig. 2). This freshly secreted substance also fixes the enlarged parasite to the substratum (e. g., petri dish, bottom of the tank, coral, etc.). Fission now begins. At room temperature (22° C.) and in sea-water with a specific gravity of 1.028, division is more or less regular and always equal. In living material, fission apparently begins in the cytoplasm diametrically opposite to the point of attachment. In other words, the plane of fission passes through the former antero-posterior axis. Subsequent divisions occur in more or less regular fashion at intervals of about twelve hours, giving rise to 2, 4, 8, 16, 32, 64 and 128 cells. Just prior to the first division, the remnant of the retracted peduncular processes completely disappears. The ocellus may or may not disappear; as observed in one case, the organelle appeared to be dividing just before the first fission was completed (Pl. I, Fig. 4). Scattered beneath the surface of the cell may be found many red pigmented rodlets ("erythrosomes"), which are constantly shifting position (Text-fig. 2, ery.; Pl. I, Fig. 2). At the end of division these rodlets usually have disappeared (Text-fig. 3, K) and in their place may be found a single red pigment bar near the surface

on each daughter cell. In other cases both ocelli and "erythrosomes" may be present at the same time. The origin and final disposition of these granules was not determined. As the cell divides some of the chromoplastids and amyloid granules pass to each daughter organism.

After the second division, a new cellulose cyst is secreted by each daughter cell at the termination of each fission, so that, when the dinospore stage is reached, each individual is enclosed in its own cyst from which it eventually escapes.

It is interesting to note that if the cells fail to divide at any particular stage within the palmella, certain changes occur in the daughter cells; these have been interpreted as degenerative. The chromoplastids take on a more pronounced yellow color while the pigment granules gradually change from a definite red to a reddish orange and finally to a definite yellow color. The ocelli, however, remain unchanged. These changes appear to be associated with a gradual dehydration of the organisms; indicated by the evaporation of water from the slide.

The amount of fluid present is another important factor for development. In the isolation experiments, if the organism is left in a hanging drop, division may occur up to the 64 or 128 cell stages, depending on the size of the parent cell and the size of the drop. In some cases where the dinoflagellate was accidentally placed at the edge of the drop, division ceased when the four cell stage was reached. However, if any of these organisms are placed in a larger body of medium or in a fresh hanging drop, division will continue even to the formation of dinospores.

Several times there has been observed an interesting process in which, after the first fission, one of the resulting daughter cells fails to undergo further division, while the other gives rise eventually to free-swimming dinoflagellates. This is the type of development ("Palisporogenesis") which occurs normally in the closely related genus *Apodinium*.

DINOSPORES.

As a rule, in the material under observation, division proceeded in a fairly regular manner to the 128 cell stage and then metamorphosis into dinospores occurred. After flagellation is completed one more division takes place to produce 256 motile individuals. However, under certain conditions (discussed below) dinospore formation by the smaller individuals may be induced at the end of the 8, 16, 32, or 64 cell stages, although never as early as the 2 or 4 cell stage. The factors inducing sporulation appear to be affected by environmental conditions (density of the sea-water, temperature, crowding, etc.) and, contrary to the belief of Brown (1934), are not necessarily related to the size of the original dividing cell.

The formation of the dinospores is an interesting process as observed in living material. Just before the final division, the amyloid inclusions become aligned in the plane of the coming fission (Text-fig. 4, N). Other granules together with the chromoplastids are distributed around the periphery of each cell. Near the surface, orange or red pigment granules of varying shapes and sizes may or may not be present. A red pigment bar with its companion black rod is present near one pole of the cell and in a later stage of development there is at each end of this black rod a granule from which a flagellum arises. In such stages this black rod appears as a "desmose" between the two blepharoplasts (Text-fig. 5, Q; Pl. I, Figs. 6-9).

As observed in permanent preparations (Pl. IX, Figs. 56-74), the neuromotor apparatus arises from what appear to be the centrioles. Certain forms show diplosomes, still within the "centrosphere," from which the flagella are growing out. As will be noted, these centrioles are joined

by a minute fibril. In later stages the fibril increases in length and eventually comes to lie at the periphery of the cell as observed in the living material. In this stage, the flagella appear to be equal in size (Pl. I, Fig. 6). Whether or not the fibril connecting the blepharoplast behave as a paradesmose in fission has not been determined definitely.

By a constant whipping of the flagella, the dinospore frees itself from the cyst wall. It moves about now and then, but it eventually becomes quiet again and then secretes another membrane (Text-fig. 5, T; Pl. I, Fig. 7). In this stage the dinospore is spherical in shape and measures about 15 microns in diameter. The cytoplasm, except for a few chromoplastids and amyloid granules, is clear and non-vacuolated. On the flagellar side, between the cellulose membrane and the periplast (Text-fig. 1, pp.), there is a large space within which lie the flagella (Text-fig. 5, T; Pl. I, Fig. 7). In fixed material only a few chromoplastids are seen in the granular cytoplasm. The nucleus is ovoid or spherical and shows comparatively short and densely stained chromosomes.

Several stages in the transformation of the early dinospore into the typical free-swimming dinoflagellate has been observed (Text-fig. 5, U-X; Pl. I, Figs. 7-10; Pl. IX, Figs. 56-74). Many of the specimens show surface depressions, which presumably will become the girdle and sulcus. These rudiments appear as clear areas, usually on one side of the body. Other flagellates have been found with transverse girdle and a very short sulcus (Text-fig. 5, V; Pl. I, Fig. 9), although the flagella had not yet assumed their final position. In this stage the stigma-neuromotor complex has receded some distance from the surface of the cell. In later stages one of the flagellum comes to lie in the girdle while the other extends posteriorly in the space between the periplast and the cellulose membrane (Text-fig. 5, U).

At the completion of metamorphosis (Text-fig. 5, W and X; Pl. I, Fig. 10; Pl. IX, Figs. 72-74), the free-swimming dinoflagellates are small organisms, measuring about 12 microns in length and about 8 microns in width. The epicone is slightly smaller than the hypocone. The nucleus is approximately central in position and shows the structure typical of the dinoflagellate nucleus. The ocellus lies to the right in the anterior hemisphere. There are a few chromoplastids and amyloid granules, usually arranged around the periphery of the cell. The transverse flagellum extends the full length of the girdle, while the longitudinal flagellum, held more or less rigidly proximally, passes posteriorly along the sulcus. In fixed preparations the fibril joining the blepharoplasts is seen paralleling the longitudinal axis of the cell (Pl. IX, Figs. 72-74).

Although the organisms move about rapidly and are very difficult to observe, it was noted that the transverse flagellum is active in swimming, causing the flagellate to rotate to the right. Lashing movements of the longitudinal flagellum drive the flagellates forward.

Transformation from Dinospore to Attached Stage.

Under natural conditions the free-swimming stage presumably invades the branchial chamber of a fish, becomes attached to a gill filament and metamorphoses into the parasitic type. This metamorphosis has not been traced completely. However, the writer has observed certain changes which appear to be stages in this transformation. In some cases both girdle and sulcus are still present but the flagella have disappeared. Observations on other stages indicate (Pl. IX, Fig. 75) that the rhizoids develop from the sulcal area. In such specimens the girdle is still present, while in the sulcus region there is a finely granular cone-shaped zone of cytoplasm, the apex of which is slightly extruded through an opening in the cellulose wall. Presumably this will eventually form the peduncle with the rhizoid processes.

Nuclear Division.

1. *Interphase.*

The "resting" nucleus of the vegetative stage of *O. ocellatum* is oval or rounded in shape, lying usually near the center of the body. In fifty specimens taken at random, the average size of the ovoid type is 20 x 16 microns. The spherical nuclei average about 16 microns in diameter, the smallest measuring about 12 microns and the largest about 30 microns. The "resting" nuclei of the dinospores are much smaller, averaging about 8 microns.

In the "resting" nucleus of the attached parasites (Pl. II, Figs. 11-24), the chromatin is present in the form of very short, densely staining "threads." With the absorption of water in the early stages of the detached parasites, the nuclei also increase in volume. In these forms, the chromatin is again apparent as short "threads," but staining very lightly with hematoxylin. This staining reaction of the nuclear substance appears to be correlated with this increase in size. Thus, after each division of the palmella (during which stage no more water is absorbed) the nuclear material stains more densely. Similar types of nuclei were reported by Calkins (1899) and Chatton (1914 and 1920) in *Noctiluca* and *Blastodinium* respectively. In both these forms the nucleus is tremendously large and superficially, at least, appears vesiculated. These investigators also reported the fact that the chromatin substance of the nucleus stains lightly with basic dyes.

There is some evidence that the nucleus in *O. ocellatum,* during certain phases of the parasitic stage, assumes an interphase in which chromatin granules (Pl. III, Fig. 25), rather than short "threads," are evident. Chatton (1920) reported this type of "resting" nucleus in young parasites and dinospores of other species of *Oodinium.* Chromatin granules were also reported by Entz (1921) for the interphase nucleus of the free-living dinoflagellate, *Ceratium hirudinella.* Other investigators such as Borgert (1910a) for *Ceratium tripos,* Jollos (1910) for *C. tripos, C. fusus* and *C. furca* and Hall (1925 a and b) for *C. hirudinella* and *Oxyrrhis marina* were unable to detect a "resting" stage in which scattered chromatin granules were present. However, no true interphase was observed in any other stage in the life-history of *O. ocellatum.* Once division is initiated, the nucleus assumes a typical prophase appearance in which the chromatin material is present in the form of chromomeres composing beaded chromosomes.

2. *Nuclear Membrane.*

A definite nuclear membrane is present in the "resting" stages of *O. ocellatum.* Chatton (1920) reported the absence of such a structure for the parasitic form of *O. poucheti,* although it was found to be present in *O. fritillaria* and *O. amylaceum.* In the vegetative stage of *O. ocellatum* the membrane is thick, but after the absorption of water it becomes very thin and plastic as is indicated by the indentations caused by the numerous chromoplastids impinging upon it (Pl. III, Fig. 25). During the early stages of division, the membrane persists but eventually it disappears and is reformed in the telophase of the first division cycle (Pl. VI, Figs. 47, 48). However, in the palmella division, the nuclear membrane is not apparent until the telophase of the last division cycle or that division which gives rise to the dinospores.

Calkins (1899) reported that in *Noctiluca* the nuclear membrane persisted during mitosis and disappeared only at the stage when the nuclear plate is formed and the chromosomes were ready for division. In this stage it disappeared in the region between the nuclear plate and the central spindle. Chatton (1914), however, finds that in *Blastodinium* the nuclear

membrane disappeared early in mitosis. On the other hand, Hall (1925 a and b) reported the persistence of the membrane throughout all the stages of the division cycle of both *Ceratium* and *Oxyrrhis.*

3. *The Achromatic Mass in the Resting Cell.*

The achromatic mass or "archoplasm" is present in the sub-nuclear area of the resting cell (Pl. III, Figs. 26-28). It is the differentiated mass of cytoplasm described above. This cytoplasm is stained light blue in Mallory preparations (Pl. II, Figs. 21-24), yellow with Van Giesen's (Pl. II, Figs. 11-16) and brownish with iron-hematoxylin (Pl. II, Fig. 20). In the preparations stained by the first two methods no fibers were evident at this stage. This achromatic mass is large and, in young attached parasites (Pl. II), appears to be continuous with or extends to the base of the peduncle. In larger forms in which retraction of the polar processes has taken place, the two areas, however, are well separated and are connected by the canal described above (Pl. III, Fig. 27).

In addition to the finely granular appearance of this differentiated cytoplasm, densely staining basophilic granules are present (Pl. II). These granules are not unlike the microsomes described by Calkins (1899) in the spheres of *Noctiluca* and by Chatton (1914, 1920) for the spheres of *Blastodinium.* In the division stages of *O. ocellatum* similar granules were found at the fork of the bifurcated strands passing out from the achromatic mass (Pl. VII, Fig. 51).

4. *Mitosis.*

The phenomena of nuclear division in *Oodinium ocellatum* are somewhat complicated, so that the following general summary will help to make the details more clear.

Two kinds of nuclear activity are recognized, one taking place in the first division of the cell, and the other in the palmelia, especially after the 8 cell stage, though not necessarily so. In the former, mitosis is not unlike that described by Calkins (1899) for *Noctiluca* and Dogiel (1908) for *Haplozoon.* Such a type is prevalent also in the sporozoans and in certain radiolarians and designated by Belar (1926) as paramitosis. The latter investigator reported such nuclear behavior for *Aggregata eberthi* and *Collozoum inerme.*

In *O. ocellatum,* as in the above species, the "sphere" which lies in the sub-nuclear region elongates during the early stages of nuclear activity. In these stages, the chromosomes are short, thin and stain lightly. Later they appear long, thick and densely stained. The nuclear membrane disappears and the chromosomes become oriented in parallel rows and at right angles to the elongated spindle. The chromosomes split longitudinally while in this stage and from each daughter chromosome mantle fibers pass to both sides of the "sphere." As the "sphere" divides, the chromosomes are gradually drawn upon the central spindle formed and in a still later stage assume a metaphase "plate" appearance. During the anaphase, the chromosomes are drawn towards opposite poles as a result of a further division of the spindle. In the telophase, the chromosomes again become short.

In later palmella stages, mitosis appears to be somewhat different and correlated with the rapidity with which division occurs. In these forms, no orientation of the chromosomes like that described above was noted. However, in late prophase or early metaphase shorter V-shaped chromosomes are present on an elongated spindle; the condition appearing not unlike that found in the metaphase stage of *Syndinium turbo* (Chatton, 1921). In *Oodinium,* however, there is no evidence that the V-shaped chromo-

somes split as a unit, i. e., from the apex of the V and along the axes of the "arms." In later stages of division in *Oodinium,* the chromosomes again appear as a "plate" and the migration of the daughter chromosomes to the poles occurs as in the first mitotic cycle.

5. *Prophase.*

Although one or more endosomes are present (Pl. III, Figs. 25, 26), there is no evidence that this structure takes an active part in mitosis. In large parasites, the endosomes vary in size and shape. They invariably stain lightly and homogenously with hematoxylin.

It is very difficult to delimit the various phases of mitosis in *O. ocellatum* and it is with some hesitancy that the terms employed for the stages of the nuclear cycle in metazoan cells are applied here. The behavior of the nucleus during the early prophase is not completely understood as yet. In Fig. 30 (Pl. IV) the nucleus is elongated, while the chromosomes are still in the shortened phase. The nuclear membrane is still present and within the "sphere" mass the centriole may be seen. In Fig. 31 (Pl. IV) the nuclear membrane has disappeared from the side towards the "sphere." In this stage the short chromosomes of the vegetative nucleus are replaced by long, thin and lightly stained ones. In this case and in others the mitotic figure superficially resembles late anaphase or early telophase, with only one pole of the divided nucleus showing. Thus, Fig. 31 (Pl. IV) is comparable to Calkins' (1899) Fig. 39 (Pl. 42) to which he refers as late anaphase. In the present material, these stages have been interpreted as early phases of mitosis in which the chromosomes have assumed a parallel arrangement but as yet have not thickened. In Fig. 32 (Pl. IV) the nucleus appears as a bilobed structure but the chromosomes are still in the prophase stage. Here, too, mantle fibers are present. Figs. 33 and 34 (Pl. IV) might indicate that the nucleus is forming a C-shaped structure and is beginning to surround the elongated "sphere" (Pl. IV, Fig. 34) somewhat like that reported by Calkins (1899) for *Noctiluca.* However, in so far as could be determined, such is not the case for both parts of each of the nuclei represented are entirely separated.

In many instances the nucleus takes on a sheaf-like appearance (Pl. V, Figs. 38, 39) and although the nuclear membrane has entirely disappeared, the chromosomes are still thin and lightly stained. In these forms, the chromosomes show definite orientation towards the "sphere."

6. *Metaphase and Anaphase.*

In the late prophase or early metaphase, of both the initial and subsequent divisions (up to and including the palmella of the 4 cell stage), the chromosomes are long, thick and rather densely stained (Pl. IV, Fig. 35; Pl. V, Figs. 36, 37, 40). They are definitely arranged parallel to one another and at right angles to the dividing spindle. At this and earlier stages (Pl. IV, Figs. 31, 32), fine mantle fibers pass from the chromosomes to the "sphere." The chromosomes have begun to move into the central spindle formed as a result of the elongation of the "sphere;" during the process some of the chromosomes, moving in opposite directions, pass each other, so that a curious picture is produced. Presumably, as in other paramitotic divisions splitting has been completed by the time the chromosomes begin to move onto the spindle. Once on the spindle, the chromosomes appear as a metaphase "plate" (Pl. V, Fig. 41). There is no evidence, however, that this nuclear "plate" encircles the central spindle as was reported by Calkins (1899) for *Noctiluca* and by Dogiel (1908) for *Haplozoon.* In *Oodinium ocellatum* the separation of the daughter chromosomes is com-

pleted by a transverse fission. This separation has just started in the form represented in Fig. 42 (Pl. V). During the anaphase the daughter chromosomes are drawn to the opposite poles (Pl. VI, Figs. 44, 45; Pl. VII, Figs. 50-51).

In later fission, after the 8 cell stage, this type of nuclear division was not observed. In the early prophase no aligment of the chromosomes was noticed. In later stages, radiating V-shaped chromosomes appear on the spindle (Pl. VI, Fig. 49; Pl. VIII, Fig. 52). The writer interprets such stages as metaphases and the chromosomes are doubling their number by unipolar splitting. As the spindle begins to divide, the chromosomes are straightened out to form the typical metaphase "plate." Division of the chromosomes is completed, possibly, by a transverse fission, much like that described by Hall (1925 a and b) for *Ceratium* and *Oxyrrhis*. Similar type of radiating V-shaped chromosomes was reported by Chatton (1920, 1921) for the parasitic dinoflagellate *Syndinium turbo*. In this form, the chromosome number is doubled by a splitting of the entire V.

7. *Telophase.*

In early telophase the chromosomes become condensed and for a short time maintain their parallel arrangement (Pl. V, Fig. 43; Pl. VI, Figs. 46, 47; Pl. VIII, Fig. 53). In late telophase (Pl. VI, Fig. 47) a nuclear membrane is reformed even before the spindle has been completely obliterated. No evidence was obtained, however, to show that in this first division cycle the reorganized nuclei assume the normal interphase appearance. In all cases seen the chromosomes remained similar to those of the early prophase (Pl. VI, Fig. 48). The nuclear membrane in such forms is thin as in the prophase nucleus at the beginning.

After the 4 cell stage, on the other hand, division is very rapid and the chromosome structure definitely is not altered in this phase but passes into the prophase of the next division (Pl. VIII, Fig. 52). In the final dinospore division, the chromosomes in the late telophase are short, thick and densely stained (Pl. IX, Figs. 56-58).

7. *Achromatic Figures.*

The process involved in the separation of the chromosomes in *O. ocellatum* is an intricate one. As was pointed out above, the achromatic mass, or "sphere" as Calkins calls it, arises from the differentiated cytoplasm in the region just posterior to the resting nucleus (Pl. II, Figs. 12-14; Pl. III, Figs. 25-27). In certain forms, "centrospheres," containing diplosomes described above, are evident (Pl. IV, Figs. 30, 33; Pl. V, Fig. 40; Pl. VIII, Fig. 52) and not unlike those present in *Noctiluca* (Calkins, 1899). From each polar mass, fine strands pass to the periphery, bifurcate and end in the periplast (Pl. VII, Fig. 51). At the fork of each bifurcation is often found a granule (not unlike the microsomes found within the differentiated cytoplasmic mass of the attached parasite), the significance of which is not known. Fig. 32 (Pl. IV) shows what might be the beginning of the fine protoplasmic strands, although the "sphere" has not yet begun to elongate. At the termination of fission, especially at the end of the first nuclear cycle, the achromatic mass is also reformed (Pl. VI, Fig. 48).

It has been shown above that from each of the divided chromosomes minute fibrils (Pl. IV, Figs., 31, 32; Pl. V, Fig. 40) pass towards the center of the "sphere." When the latter elongates to form the central spindle these fibrils converge towards each pole. These are in all probability the radial fibers described by Ishikawa (1899) and the mantle fibers described by Calkins (1899) for *Noctiluca*. The exact relationship of these fibers to those

of the spindle was not determined for *O. ocellatum*. Calkins, although not certain, believed they were nuclear in origin. He showed that these fibers are focused in the centrosome and connect with the chromosomes. Although in *O. ocellatum* fibers were seen passing from the chromosomes, just how far they extended along the spindle could not be ascertained, for in many of these forms no centrosomes were evident. In palmella divisions definite centrioles within centrospheres were often present but no mantle fibers were found. One detached parasite showed two centrospheres in the posterior region of the body connected by minute fibers passing from the differentiated cytoplasmic mass (Pl. VIII, Fig. 55). This would indicate that these fibers at least, are not nuclear in origin.

The centrioles arise as a result of the division of the granules and desmose of the ocellus complex. In one case such a divided structure was seen within a centrosphere-like structure (Pl. VIII, Fig. 54). In the specimen mentioned above, two such centrospheres were present in the granular zone of the posterior part of the cell (Pl. VIII, Fig. 55). Unfortunately, in most of these stages, the nucleus and the surrounding region are partially masked by the large number of chromoplastids and the relationship of this structure to the nucleus could not be determined. However, it is believed that these fibrils focusing towards the centrosphere are in direct connection with the achromatic mass adjacent to the nucleus. Just how they finally attain their final position at the poles of the spindle was not determined.

As just stated, the centrioles arise as a result of the division of the granules and desmose of the ocellus complex. It must be mentioned here, however, that in the living parasite, no granules were observed at the ends of the black pigment bar associated with the red pigment mass of this organelle, although they were quite evident in the early living dinospore stage. However, in all these non-flagellated forms, the red part of the ocellus is always connected to the black portion by means of very minute "fibrils." It may well be that these connecting fibrils condense to form the granules (blepharoplasts) present in the centrosphere. The evidence for the origin of these centrioles from the ocellus complex is further substantiated by the fact that these granules give rise to the flagellar apparatus while still within the centrosphere (Pl. IX, Figs. 64-66).

No definite evidence was obtained as to the presence of a paradesmose such as has been described for many of the free-living flagellates. Hall (1925 a) was the first to demonstrate such a structure in a dinoflagellate. He found that in *Oxyrrhis marina* a paradesmose was formed as a result of a division of the centrosome. In this form the blepharoplasts disappear during late prophase or early metaphase. Therefore in this species, at least, the "desmose" is a centrosome-paradesmose. Kofoid and Swezy (1921) consider the achromatic structure of *Noctiluca* as analogous to the centrosome-paradesmose of other flagellates, since in this form the kinetic elements are extra-nuclear throughout the entire process of mitosis. By the same reasoning, since the centrospheres and spindle are also extra-nuclear in origin, the entire organelle in *O. ocellatum* may be considered analogous to a paradesmose. In this form, however, since it is definitely shown that the centrioles are in fact the blepharoplasts which give rise to the flagella of the dinospores, the desmose may be considered as analogous to a centroblepharoplast-paradesmose of the free-living flagellates.

It must be mentioned here, that in several cases a peculiar fiber was noted, the ends of which terminated in small granules and from each of which two small fibrils pass out to join each of the granules in the centrospheres (Pl. VIII, Fig. 53). If this is a paradesmose, it is possible that with the proper technique this structure can be demonstrated more definitely.

8. *The Mechanism of Mitosis in* Oodinium ocellatum.

There are many theories concerning the mechanism of mitosis in general. Calkins (1899) reported his concept of this process in *Noctiluca*. He states "The nuclear membrane disappears and the mantle fibers connect the ends of the chromosomes with the centrosomes in the spheres. The central-spindle elongates, causing separation of the spheres; the mantle fibers, remaining firm, move with the spheres, dragging the ends of the chromosomes with them. As the central-spindle becomes longer, the chromosomes are more and more separated, until finally the distal ends are separated and the chromosome division is completed." This process seems logical enough, but the question may be asked, what causes the spindle to elongate? The writer believes that the following may throw some light on this question.

In practically all the division stages of *Oodinium ocellatum* a seemingly sol-gel reaction of the cytoplasm was noted. The "sol" phase manifested itself in stained preparations as light and non-granular areas, usually at the poles of the cell (Pl. VII, Fig. 51). The fine strands passing out from the "sphere" seem to be attached to the edges of such zones. A gradual gelation occurs towards the poles of the cell. With this reversal of phase, the strands of the spheres are "pulled" towards the poles, resulting in the elongation and finally the division of the spindle and the separation of the chromosomes on it. At the beginning of division these strands radiate out in all directions. As division proceeds (and the cell elongates) the strands begin to converge more and more towards the poles. When fission is completed, solation once again occurs, the cell rounds up and the protoplasmic strands radiate out in all directions.

It is interesting to note that Calkins (1899) had seen similar strands passing out from the "sphere" of *Noctiluca* but interpreted them as analogous to the astral rays of metazoan cells. Their function in the division processes of the dinoflagellate, however, was not discussed.

Effects of Density of Sea-water on *Oodinium*.

It was shown by Nigrelli (1935) that the monogenetic trematode *Epibdella melleni* MacCallum was unable to withstand sea-water of either a high or low density. A similar experiment was carried out to determine the optimum density necessary for complete development of these dinoflagellates and the effects of densities at either extreme.

Small quantities of modified sea-water with specific gravities ranging from 1.040 to 1.003 (pH range from 8.4-7.1) were made up as described under material and methods. Aliquot portions were distributed to petri dishes and to each dish were added parasites taken directly from the gills of several spiny boxfish. Examination of each dish immediately after the parasites were placed therein showed that all the flagellates were in the vegetative stage (i.e., with the peduncle and rhizoid processes still protruding). At the end of each twenty-four hours a differential count was made of the various division stages present. This was continued for a period of seven days.

The results showed that the optimal density for development to the dinospore stages lies between 1.012 and 1.021. It is interesting to note that within this range all forms may develop into dinospores at the end of the second or third day. At a density of 1.040, division occurred very slowly and dinospores were not formed during the period of our observations. In the majority of specimens, at this density, development reached the 16 cell stage, and only 2% were seen in the 32 cell stage. However, if the organisms were transferred as late as the sixth day to sea-water of lower density (1.028), division continued to the 128 cell stage and dinospores were formed.

At a density of 1.036 division was slow and again a few non-motile dino-spores were observed only at the end of the seventh day. In water with specific gravities of 1.034 and 1.032, non-motile dinospores were seen on the fourth and sixth days, and the majority became free-swimming on the seventh day. In densities of 1.030, 1.029 and 1.028 non-motile dinospores were observed as early as the third and fourth days; a few free-swimming dinoflagellates were present on the fifth day and practically all were motile on the sixth and seventh days. In a density of 1.024 many non-motile dinospores were noted on the third day; these became active twenty-four hours later. In the densities of 1.021, 1.018, 1.015 and 1.012 a few non-motile dinospores were observed on the second day, but they did not become free-swimming until the fourth day. In densities of 1.005 and 1.003, the or-ganisms divided very slowly. At the end of the fifth, sixth and seventh days the majority of forms were in the 8 and 16 cell stages and a few non-motile (32 cell stage) dinospores were observed. In fresh water, develop-ment continued to the 4 cell stage, and only 18% reached the 8 cell stage. At the end of the experiment (seven days) these 4 and 8 cell stages were trans-ferred to sea-water having a density of 1.009, but no further division oc-curred. Development in water with a specific gravity of 1.003 was similar to that in fresh water, except that on transfer of the palmellas to a density of 1.009, division continued in a few instances and dinospores were formed. Again, however, most of the palmella reached only the 16 cell stage.

These experiments were carried on at an average temperature of 22° C. In another series, the temperature was varied while the specific gravity was kept constant at 1.028. At 12.5° C., the development was very slow, a few non-motile dinospores being formed at the end of seven days while the majority (60%) were in the 128 cell stage. At this temperature, most of the dinospores did not become free-swimming until the end of the tenth day. At 25° C., the results were somewhat similar to those obtained at room temperature, with a few non-motile dinospores being formed as early as the third day and motile flagellates at the end of the fifth day. At 35° C., development was accelerated considerably at this density. Here, the rate of division was somewhat equivalent to that which occurred in sea-water with a density of 1.015 and at 22° C.

Similar results were obtained by Brown (1934), who found that the organisms were inactive below 10° C. From 10-20° C., the flagellates divided slowly; from 20-25° C., more rapidly, and at about 25° C., sporula-tion was completed in three days.

These results indicate that the densities most suitable for development lie between 1.012 and 1.028. This is approximately the range observed under natural conditions. However, it is interesting to note that development can occur (at room temperature) over a wide range of specific gravities (1.005-1.036).

At the height of the epidemic in the Aquarium, analysis of the water gave the following readings:

	Density	pH	Temp.	Bound CO_2 mM per liter	Free CO_2
Bay Water	1.0120	7.5	22° C.	2.02	.20
Sea Water	1.0284	8.2	22° C.	2.50	.00

Conditions in the Aquarium were well within the range most suitable for development of *Oodinium ocellatum*. The heaviest infection was found

in fishes in the closed circulation. This was no doubt due to the fact that the infective stages were not washed to the sewer as would be the case in the open circulation or bay water. Therefore, the results obtained in the laboratory compare favorably with the conditions present in the tanks.

<div align="center">TAXONOMY.</div>

According to Chatton (1920), one of the first parasitic dinoflagellates to be discovered was *Gymnodinium pulvisculus,* described by Pouchet (1884-1885). Since the specific name had been previously applied by Klebs (1883) to a fresh water type, Lemmermann (1899) renamed the parasite *Gymnodinium poucheti.* In view of the great variety of forms included in the genus *Gymnodinium,* Chatton (1912) erected the new genus *Oodinium* with *O. poucheti* (Lemmermann, 1899) as the type species. The genus is defined by Chatton (1920) as follows: "Dinospores à hémisphère antérieur beaucoup plus développé que le postérieur. Pas de pigment Xantho-chlorophyllien, mais un lipochrome. Formes végétatives fixée par un tronc absorbant fibrillaire. Parasitisme blastotrophe. Pas de scissiparité simple. Sporogénèse intervenant après libération du parasite à produits, homodynames épars." Chatton gave this genus, as he did for many other genera of parasitic dinoflagellates, family (Oodinidae) ranking under the sub-order Gymnodinida. However, both Kofoid and Swezy (1921) and Calkins (1926) relegated all the known parasitic genera to a single family, Blastodinidae Chatton, 1906. In this family, they included the following genera: *Schizodinium* Chatton (1912). *Blastodinium* Chatton (1906). *Apodinium* Chatton (1907), *Parapodinium* Chatton (1920), *Chrytriodinium* Chatton (1912), *Paulsenella* Chatton (1920), *Haplozoon* v.Dogiel (1906 a) (= *Microtoeniella* Calkins, 1915), *Oodinium* Chatton (1912), *Syndinium* Chatton (1910 a), and *Trypanodinium* Chatton (1920). However, Kofoid and Swezy (1921) failed to include *Haplozoon* and, furthermore, they included as true dinoflagellates the genera *Ellobiopsis* Caullery (1915) and *Paradinium* Chatton (1910), two forms which, according to Chatton (1920), are perhaps not dinoflagellates but were provisionally placed in the sub-order Cryptomonadinea because of their cryptomonad-like characteristics. More recently, Reichenow (1930) classified all these forms under the family Gymnodiniidae and added the genera *Endodinium* Hovasse (1922) and *Merodinium* Chatton (1923) to the group of parasitic dinoflagellates.

The genus *Oodinium,* according to Chatton (1920), contains the following species: *O. poucheti,* from the tunicate *Oikopleura dioica; O. amylaceum* (Bargoni, 1894), occurring on *Salpa mucronata* and *S. democratica; O. fritillaria* Chatton (1912) from *Fritillaria pellucida,* and *O. appendiculariae* (Brooks and Kellner, 1908) from the acidian, *Oikopleura tortugensis.* Other species of doubtful identity but temporarily placed by Chatton in the genus *Oodinium* are forms described by Dogiel (1910) as *Gymnodinium pulvisculus* from the annelid *Alciope* sp. and one form that Chatton (1920) has observed on the pteropod *Criseis acicula.* Kofoid and Swezy (1921), in their short discussion of parasitic forms, refer to a species as *Oodinium parasiticum* (= *Gymnodinium parasiticum* Dogiel, 1906). According to Chatton, *G. parasiticum* Dogiel is synonymous with *Chytriodinium parasiticum* (Dogiel).

The life-history and morphology are not completely known for any of the above species of *Oodinium.* In *O. poucheti,* according to Chatton (1920), the parasitic forms are large in size (150-200 microns), ovoid or spherical, without groove or flagella. The cytoplasm contains numerous minute yellow lipochrome granules more or less evenly dispersed. The vesicular nucleus is large. The organ of attachment is made up of a short robust peduncle,

possessing fibrils and terminating in fine rhizoids, which, as in *O. ocellatum,* are capable of retraction. The entire body, including the rhizoids, is surrounded by a cellulose membrane. Reproduction occurs by repeated and equal division, resulting in the development of numerous free swimming, naked dinospores, with a girdle but no sulcus. The details of fission and metamorphosis of the dinoflagellate to the parasitic type are not known.

O. amylaceum was originally described by Bargoni (1894) as one of the Foraminifera and it was Chatton who recognized its true relationships, although palmella and dinospore stages have not yet been described. In this form, the peduncle terminates in an extensive arborization of rhizoids. The cytoplasm contains numerous amyloid granules. Caullery (1906) rediscovered this parasite in the branchial cavity of *Salpa africana* but gave no information on its life-history. However, from the figure he submitted to Chatton (see fig. 4, Chatton, 1920) the rhizoids do not show the characteristic arborization and in all probability it may be another species.

O. fritillaria measures 80 x 130 microns (115 microns in diameter for the round forms). The nucleus in this species is very large, measuring 75 microns in diameter. There are a few yellow lipochrome granules in the cytoplasm. This form differs from the other described species in that the organ of attachment terminates in a broad basal disc measuring 60 microns in diameter. Division and dinospore stages are not known.

O. appendiculariae was first described by Brooks and Kellner (1908) as stages in the development of *Oikopleura tortugensis* and in the same paper (page 93) reported certain forms as a new species of parasitic Foraminifera (*Gromia appendiculariae*). It was Chatton (1920) who pointed out that these attached forms were parasitic dinoflagellates, although no other stages in the life-history are known.

Oodinium ocellatum agrees with the general generic description given by Chatton; since the morphology and life-history of the various species are but imperfectly known, it is difficult, however, to determine specific differences. According to Brown (1931), it "differs from all other members of the genus in the possession of an eye-spot and in its somewhat smaller size." However, there are other differences, some of which are given in the comparison with the type species, *O. poucheti.*

There is no doubt that the dinoflagellate found on fishes belongs to the genus *Oodinium.* Since the generic characters are based on *O. poucheti,* this species may be compared with *O. ocellatum.* The parasitic stage of *O. ocellatum* differs from that of *O. poucheti* in the following characters: (1) presence of chromoplastids and amyloid granules, (2) cellulose cell wall surrounds the body of the parasite, the peduncle and rhizoids being naked, (3) presence of one or more eye-spots, (4) the absence of yellow lipochrome granules, but the presence of red or orange pigment rodlets or globules during certain stages of development and (5) the presence of a peculiar "flagellum" originating in the peduncle. The free-swimming dinoflagellate differs from those of *O. poucheti* in the following: (1) hypocone slightly larger than epicone, (2) presence of a definite, although small sulcus, (3) presence of a few small chromoplastids and amyloid granules in the cytoplasm, (4) red eye-spot and (5) presence of definite cellulose membrane surrounding the entire organism. *O. ocellatum* agrees with *O. poucheti* in the following: (1) the parasitic stage is usually pyriform-shaped organism of rather large size with organelle of attachment composed of a peduncle ending in fine rhizoids, and (2) division is usually equal, giving rise to a palmella with subsequent formation of free-swimming dinospores.

Because the life history of the majority of the species of *Oodinium* is not entirely known, the following tentative key is formulated on the basis of certain characteristics found in the parasitic stage.

Key to the Species of Oodinium *Chatton,* 1912.

A₁ Peduncle terminating in few rhizoids
  b₁ no eye-spot present .... 1. *O. poucheti* (Lemmermann, 1899)
  b₂ eye-spot present .... 2. *O. ocellatum* (Brown, 1931)
A₂ Peduncle ending in a broad disc ... 3. *O fritillaria* (Chatton, 1912)
A₃ Peduncle ending in an extensive arborization of rhizoids
          4. *O. amylaceum* (Bargoni, 1894)

Such forms as *O. appendiculariae* (Brooks and Kellner, 1908), *Oodinium* sp. (Dogiel, 1910) and *Oodinium* sp. Chatton (1920) are not included because structural details of the type to distinguish them from the species listed in the key are not known. However, on the basis of the little that is known about the parasitic stage, there can be but slight doubt that these forms belong to the genus *Oodinium.*

INCIDENCE OF INFECTION IN THE NEW YORK AQUARIUM.

According to Brown (1934), the evidence shows that *Oodinium ocellatum* is "indigenous to the warm latitudes and is probably associated with coral reef fishes in Bermuda and the East Indies." The majority of fishes in the New York Aquarium are collected from Key West, Florida, and from Sandy Hook Bay for local species. An occasional specimen reaches the Aquarium from Africa and the East Indies. As was pointed out above, the center of the infection was localized in the spiny boxfish (*Chilomycterus schoepfii*) and the northern or common puffer (*Spheroides maculatus*). The former is commonly found in the more southern waters and only in late summer or early fall does it visit the waters around New York, while the latter is common about our coast from early spring to early winter. Where they go in the late winter is not definitely known.

These species, together with the majority of others caught in local waters, are first kept in bay water at seasonal temperatures and as cold weather approaches they are gradually transferred to heated bay water (22° C.). Since the parasites did not make their appearance in the closed circulation until the early part of December, 1935, the question arose as to what fish served as the original host of the dinoflagellate. Spiny boxfish present in the floor pools (not connected with either the main or warm bay water circulation) showed heavy infection and it is assumed that they brought the parasites with them in their migration from warmer waters and infected other fishes present in the Sandy Hook region at the time.

A list of infected hosts all collected from Sandy Hook Bay follows: Order Acanthopteri (spiny rayed fishes), family Carangidae: (1) *Caranx hippos* (Linn.), common jack, infection mild; (2) *Caranx crysos* (Mitchill), hard-tailed jack, infection mild; (3) *Trachinotus falcatus* (Linn.), round pompano, infection mild; (4) *Naucrates ductor* (Linn.), pilot fish, infection mild. Family Pomatomidae: (5) *Pomatomus saltatrix* (Linn.), bluefish, infection mild; (6) *Roccus lineatus* (Bloch), striped bass, infection mild; (7) *Centropristis striatus* (Linn.), common sea bass, infection mild. Family Sparidae: (8) *Stentomus chrysops* (Linn.), northern porgy, infection mild. Family Sciaenidae: (9) *Cynoscion regalis* (Bloch and Schneider), weakfish, infection mild; (10) *Leiostomus xanthurus* Lacépède, spot, infection mild; (11) *Menticirrhus saxatilis* (Bloch and Schneider), northern kingfish, infection mild. Family Tetradontidae: (12) *Spheroides maculatus* (Bloch and Schneider), northern swellfish or common puffer, infection heavy. Family Diodontidae: (13) *Chilomycterus schoepfii* (Walbaum), spiny boxfish, infection heavy. Family Triglidae: (14) *Prionotus carolinus* (Linn.), Caro-

lina sea robin, infection mild; (15) *Prionotus evolans* (Linn.), striped sea robin, infection mild. Two species collected from Florida were found infected in the Aquarium. These were (16) *Chaetodipterus faber* (Brousset), spadefish, and *Pomacanthus paru* (Bloch), French angelfish. Both of these belong to the family Ephippidae and the former was found to be mildly infected while the latter species died as a result of a very heavy infection.

A few of the species found infected by Brown (1934) are also present in the New York Aquarium, but forms from the West Indies, such as *Angelichthys isabelita* Jordan and Rutter, *Chaetodon capistratus* (Linn.) and *Holocentrus ascensionis* Osbeck, have not as yet shown signs of infection. The cosmopolitan species, *Mugil cephalus*, also present in the Aquarium, is likewise free of the parasites. The East Indian form, *Amphiprion percula* Lacépède, has never shown signs of infection in the Aquarium, although Brown reported that this species and *Psettus argentus* Linn. are always heavily infected and probably introduced the infection into the London Aquarium, indicating that the parasite is present in their natural locality.

It is interesting to mention at this time that swarms of dinoflagellates have been reported from the New Jersey coast by Martin and Nelson (1929) and since "red water" has been seen on many occasions in Sandy Hook Bay by the writer, it is altogether possible that the source of the New York Aquarium infection may be localized in this area.

Transmission Experiment.

Fundulus heteroclitus (Linn.), the common killifish, although present in large numbers in the Aquarium, was never found infected. This is not due to a natural resistance since infections have been induced under experimental conditions. A number of these fish, acclimated to a temperature of 22° C., were placed in two-gallon tanks. In two of the tanks eight fish each were introduced, while a third tank with four fish was used as control. In tank I, a large number of dinospores collected from forms grown in petri dishes were released. In tank II, the gills of a heavily infected spiny boxfish were introduced. Examination of the gills of two killifish removed from tank I on the second day gave positive results. This was to be expected because the infective stages had been introduced in large numbers. Two fish from tank II, in which infected gills with adult parasites were introduced, gave negative results on the second day, and similar results were noted in a fish examined on the fourth day. On the sixth day, however, a fish showed a mild infection. One individual found dead on the eighth day showed a heavy infection of the gills and skin, probably the cause of its death. Since all the parasites undergo a period of division when they are once removed from the gills, it is not surprising to find that infecting the fish in tank II was delayed until the sixth day.

Discussion.

Four definitely recognized species and three additional species of doubtful validity were placed in the genus *Oodinium* by Chatton (1920). Of these, the life-histories of but two species (*O. poucheti* and *O. ocellatum*) are known. The former is parasitic on the pelagic tunicates, *Oikopleura dioica* and *Oikopleura* sp., while the latter occurs on the gills and skin of marine fishes. Of the ten or more genera of parasitic dinoflagellates, the following five are ectoparasitic: *Apodinium* Chatton (1907), *Parapodinium* Chatton (1920), *Chytriodinium* Chatton (1912), *Paulsenella* Chatton (1920) and *Oodinium* Chatton (1912). *Paulsenella* was described as parasitic on

a diatom and *Chytriodinium* as ectoparasitic on copepod eggs. The genera *Parapodinium* and *Apodinium* are found exclusively on pelagic tunicates, while species of *Oodinium* have been reported from tunicates, pteropods, siphonophores and annelids. *Oodinium ocellatum* is the first known dinoflagellate parasite of vertebrates. Brown (1931, 1934) reported this species from the gills and skin of marine fishes of the East and West Indies, while the writer has found that in the New York Aquarium the parasite attacks the spiny boxfish and the common puffer. The former is a warm water species that migrates north on the Atlantic coast during the late summer and early fall; the latter, a local species ranging as far north as the coast of Maine. Other North American species, cited above, have also shown the infection.

In the Dinoflagellida, as in other groups of plant-like flagellates, many species carry on photosynthesis and are thus holophytic, while others are predominantly saprozoic or holozoic in nutrition. As pointed out by Brown (1934), *Oodinium ocellatum* is saprozoic during its parasitic stage and growth continues until the organism severs its connection with the host tissues. In addition to saprozoic nutrition, however, there is some evidence that *O. ocellatum* may carry on photosynthesis. Laboratory cultures were carried successfully in filtered and sterilized sea-water. In addition, the presence of chromoplastids and the demonstration of starch in the flagellate suggests the possible importance of holophytic nutrition in the unattached stages of the life-history. Combined methods of nutrition have been reported for other dinoflagellates, e. g., the holozoic-holophytic type in *Gymnodinium* (Kofoid and Swezy, 1921). The chromoplastids, apparently the structures referred to as "refringent granules" by Brown, are usually a pale to a definite green in color and in degenerating cells take on an ochre coloration. Such chromoplastids have never been recorded for *Oodinium*, although they have been reported for other parasitic dinoflagellates (e. g. *Paulsenella*). Amyloid granules, similar to those observed in *Oodinium ocellatum*, have been described in all the recognized species of the genus.

The ocellus of the parasitic stage of *O. ocellatum* appears to be a true eye-spot (as defined by Kofoid and Swezy), but of a primitive type, intermediate between the simple stigma and the more complex ocellus of the Pouchetidae. In *O. ocellatum* a black and a red pigment bar are associated, but whether or not a definite hyaline lens is present between them could not be determined, although the area between the two bars is highly refractile. For the Pouchetidae, on the other hand, the ocellus is made up of two parts, a refractile, hyaline lens and a pigment mass, the melanosome. The simplest form of melanosome is one in which there is a loose aggregation of pigment granules massed together on one side of the lens. In the more highly developed types, the core of the melanosome contains a red pigment.

The behavior of the more complex types of ocelli during division is entirely unknown. As was mentioned above, the ocellus in *Oodinium ocellatum* may disappear at the beginning of division only to re-appear at the end of the process. In one case, however, the ocellus seemed to be dividing. It was seen as an elongated structure near the surface between the dividing cell and was devoid of the black pigment bar. This phenomenon may not be so rare as the writer's observations might indicate, but there is nevertheless no evidence that the ocellus usually divides in fission. The red pigment rods ("erythrosomes") here observed for the first time in *Oodinium*, usually did not appear in the cytoplasm until the beginning of each division and after the ocellus had disappeared. At the end of division, the red rodlets disappeared, and the elongated ocelli were again formed at the periphery of each daughter cell. This might suggest the breaking up of the red pigment of the ocellus into small rods at the beginning of fission, such as was reported by Hall and Jahn (1929) for the granules of the stigma of *Euglena*. In other cases, however, both ocellus and erythrosomes were present at the

same time. Evidence derived from degenerating cells also seems to indicate that the erythrosomes and the ocelli are not of the same nature. Thus, just prior to cytolysis the erythrosomes would change in color from red to orange-red, orange and finally to yellow while the ocelli always remained red. When cytolysis finally occurred the erythrosomes immediately disappeared while the ocelli separated in two parts (black and red), persisted for some time as such but eventually disappeared in the sea-water. The latter observations agree with the findings of Kofoid and Swezy (1921) for the ocellus of *Erythropsis extrudens*.

The "canal" described by Brown for the parasitic form of *O. ocellatum* was also noted in the stained preparations of the writer's material. This "canal" which is stained lightly with eosin, extends from the peduncle to the achromatic mass in the vicinity of the nucleus, and is perhaps involved in the intake of fluid, as in certain free-living species (Kofoid, 1909). Brown (1934) also regards this canal as homologous with the canal of the free-living dinoflagellates, but the achromatic mass in which it terminates is interpreted by her as the sac-pusule (associated with the canal in free-living forms). The writer was unable to observe the small vesicle described by Brown as emptying into the "canal" and interpreted as a collecting pusule, such as described by Schütt (1895). In the division stages or in the free-swimming forms of *O. ocellatum,* no "canal" or related structures were observed either by Brown or by the writer.

Contractile fibers in the peduncle, such as reported by Brown, were not observed in the present material. Fibers of this sort were reported by Dogiel (1910) for *Oodinium* sp. and by Chatton (1920) for *O. fritillaria.* The latter investigator figured and described a complicated mass of fibers passing from the broad basal disc of *O. fritillaria* and inserting in a granular mass of cytoplasm adjacent to the nucleus. These fibers, according to Chatton, are used in expanding or retracting the disc. Although similar fibers are figured by Dogiel (1910) for *Oodinium* sp., he does not discuss them in his text. On the other hand, he does refer to the "pseudopodial" behavior of the rhizoids. In the present material, the rhizoids behave as "pseudopodia" during retraction. Brown (1934) reported that the fibrils were seen in the "stalk" of the attached parasites of *Oodinium ocellatum.* In the writer's material, no such fibers were noted in attached parasites stained either with Mallory's triple stain or by Van Giesen's method.

In the genus *Oodinium* sporulation has been observed in three species, *O. poucheti, O. amylaceum* and *O. ocellatum,* and the present investigation is the first in which most of the morphological changes have been observed. The general features of sporulation in *O. ocellatum* have been discussed by Brown (1934), who noted that the parasitic form begins to divide, regardless of size, once it is detached from the gills of the host. This observation has been verified in the present investigation. The writer has found that just before division begins there is a sudden increase in size of the flagellate as a result of imbibition of water; this is contrary to Brown's statement that no further increase in size occurred in water. The association of imbibition of water with the division cycle has been reported previously by Entz (1931), who showed that *Ceratium hirudinella* increases in size in this manner immediately following the division and that such a process takes place only at this period in the life-cycle. Later increases are due to real addition of living substance.

With the exception of the members of the two genera, *Oodinium* and *Paulsenella,* the ectoparasitic dinoflagellates sporulate by a process designated by Chatton (1920) as "palisporogénèse." In this type of reproduction, the first division, which is transverse, gives rise to two daughter cells. One of these cells divides repeatedly, eventually giving rise to free-swimming dinospores, while the other merely increases in size at first. However,

when sporulation is completed in the first line, the second of the original cells divides into two cells, one of which gives rise to a second generation of dinospores. As reported elsewhere in this paper, a somewhat similar process has been occasionally observed in *Oodinium ocellatum*. In this case, one of the two original daughter cells gave rise to dinospores at the end of the 32 cell stage, while the second merely increased in size. However, it was not noted if the latter cell also gave rise to dinospores.

Under certain experimental conditions (density and temperature of sea-water) division of *O. ocellatum* is more or less a regular process giving rise to palmellas of 2, 4, 8, 16, 32, 64, 128 and 256 cells. The products of the last division are flagellated dinospores. According to Brown (1934), temperature is the important factor influencing sporulation, and she found the optimum to lie between 23° C. and 27° C. The writer has shown that density of the sea-water is another factor important in the development of the flagellated stages. These results are also of interest in their bearing on the adaptability of *O. ocellatum*. Kofoid and Swezy (1921) have pointed out the delicate nature of the majority of the unarmored dinoflagellates, which are extremely sensitive to handling and to changes in salinity, temperature and pressure. *Oodinium,* on the other hand, is a very hardy type and is more nearly comparable with such forms as *Oxyrrhis, Amphidinium* and *Gymnodinium* which Kirby (1934) described from the salt marshes in salinities ranging from 3.5% to saturation.

The morphological changes involved in the transformation from the parasitic type to the free-swimming dinospores have not been recorded previously for any of the species of *Oodinium* or for many of the parasitic dinoflagellates. The movement and alignment of amyloid granules in the binucleate stage of the dinospore, the development of the neuromotor apparatus from the stigma complex, the secretion of a new cellulose membrane, the development of the girdle and sulcus, the migration and orientation of the neuromotor apparatus to its final position in the free-swimming stage are observed here for the first time. Presumably, similar morphological changes may be expected in comparable stages in the life-histories of other species.

The changes in the metamorphosis from the dinoflagellate stage to the parasitic type are also described for the first time. As was mentioned above, the flagellar apparatus is lost and the sulcus widens out to form a cone-shaped structure, the tip of which becomes extruded and possibly gives rise to the peduncle and all its processes.

The development of peculiar structures from the sulcal region has also been reported in other dinoflagellates. The pseudopodia described by Zacharias (1899) for *Gymnodinium,* the prod of *Erythropsis* (Hertwig, 1884), and the tentacles of other species are all developed from an extremely plastic sulcal area. In nearly every case, with the development of these specialized structures, there is a loss of one flagellum, usually the longitudinal one. In *Oodinium,* however, both flagella are lost, and the girdle disappears completely in growth of the more or less pear-shaped parasitic stage.

Nuclear division in *Oodinium ocellatum* is of the paramitotic type and similar in some respects to the process described by Calkins (1899) and Ishikawa (1899) for *Noctiluca.* As in *Oodinium,* Calkins noted the sphere in the resting cells while Ishikawa had only observed this structure in later stages of division. Chatton (1920) has figured (Pl. 1, Fig. 10) a similar differentiated mass of cytoplasm lying adjacent to the nucleus of *O. fritillaria.* However, the significance of this mass was not discussed. In the parasitic stage of *O. ocellatum,* this mass of cytoplasm extends to the region of the peduncle and contains many basophilic granules (microsomes). According to Calkins, these microsomes are first found in a peripheral zone of the sphere in *Noctiluca* and only as division approaches do these granules become concentrated within the sphere. The relation of these granules to

mitosis is not known. In late stages of division of *Oodinium* similar granules are found localized in the "forks" of the bifurcation of the strands passing from the spheres.   Chatton (1914, 1920) reported siderophilic granules in the centrosphere of *Blastodinium* but gave no explanation as to what they might be.   In this species, the archoplasm or sphere is composed of a granular central zone and a more or less thick, homogenously-staining peripheral zone.   Its appearance in the vegetative stage is not reported.   However, in certain trophocytes (binucleate stages) centrospheres with astral rays surrounding them are present at opposite poles of large nuclei.   Each nucleus contains several nucleoli and is traversed by filaments which he terms plasmodendrites.   These are the remains of the nuclear spindle fibers formed by the division of the centrosphere.   He points out further that these peculiar structures are formed in sporocytes of all ages, but in the last sporocyst division the centrospheres and achromatic figures disappear and a simple type of "haplomitosis" results.   In both *Noctiluca* and *Oodinium*, however, "spheres" are noted throughout all the division stages, and, in *Oodinium* at least, up to and including the last dinospore division.   Dogiel (1908) has also seen spheres with central spindle in *Haplozoon armatum* but here again the early stages in the formation of this extra-nuclear structure were not observed.

The behavior of the spindle in *O. ocellatum* during division is somewhat different from that of *Noctiluca*.   In the latter, according to Calkins, it elongates as the prophase chromosomes are being formed and at the end of this nuclear phase it consists of two daughter-spheres connected by a "central-spindle."   The nucleus elongates and bends to form a C-shaped figure and the central spindle sinks into the depression.   The spindle, therefore, lies in the secondary axis of the nucleus, which encircles it, the sphere alone remaining outside.   When the nuclear plate is formed, it is wrapped around the spindle like a ring, the chromosomes lying midway between the two poles.   A similar arrangement of the nuclear plate was noted by Dogiel (1908) for *Haplozoon*.   In *O. ocellatum* no such behavior of the nucleus was observed.   In the early stages of division, the achromatic mass elongates.   The chromosomes elongate, thicken and lie in parallel rows at right angles to the dividing spindle.   As in *Noctiluca*, the chromosomes at this stage are attached to the spindle by means of mantle fibers and as further division of the spindle occurs they eventually form a "plate."   However, there is no evidence that this "plate" encircles the extra-nuclear spindle as in *Noctiluca* and *Haplozoon*.

According to Calkins (1899), this behavior of the spindle and the chromosome is a constant feature throughout all the division stages of *Noctiluca*. However, in *Oodinium ocellatum*, it has been observed that, after the 4 cell stage, the arrangement of the chromosomes, prior to forming the "plate," is different.   In these forms no early prophases were noted. Here division is more or less rapid and the chromosomes, instead of orienting themselves in parallel rows and at right angles to the elongated spindle, are present as thin, radiating, V-shaped structures within the "sphere." Presumably, these V-shaped chromosomes straighten out as the spindle elongates to form a typical "plate."   It is further assumed that the division of the chromosomes is completed by a transverse fission, much like the condition reported by Hall (1925 a and b) for *Ceratium* and *Oxyrrhis*. Chatton (1920, 1921) reported similar radiating V-shaped chromosomes for the parasitic dinoflagellate *Syndinium turbo*.   In this form, however, the chromosomes are doubled by a longitudinal splitting of the entire V, starting at the apex and continuing along both "arms."   There is no evidence that such a process is present in the late palmella stages of *Oodinium*.

In the free-living dinoflagellates, "spheres" of the type found in *Noctiluca* and *Oodinium* have not been definitely reported.   According to Kofoid and Swezy (1921), in certain of Borgert's (1910 a) figures of *Ceratium*

tripos there are suggestions of an archoplasmic structure corresponding to spindle and polar regions. Hall (1925 a) reported a similar condition in *Oxyrrhis*. He states that "In one case (Pl. 28, Fig. 13), a noticeable difference in the two poles of the nucleus is seen; at the anterior end the chromosomes have not yet converged, but seem to extend to a clear area of the cytoplasm. This condition is quite similar to that at the ends of the amphiaster of *Noctiluca* (Calkins, 1899, Pl. 42, Fig. 31), the clear area of the cytoplasm resembling a centrosphere of metazoan cells." In the encysted stage of *Ceratium hirudinella*, reported by Hall (1925 b), a closer similarity to the condition found in *Noctiluca* and *Oodinium* is present. Thus, Hall figures and describes for this form a U-shaped nucleus (pl. 8, figs. 35-36) and in the subnuclear area (pl. 8, figs. 35, 37, 38 and text-fig. D, 1-6) may be seen a differentiated mass of cytoplasm that strongly suggests the "sphere" of the resting and early stages of division of *Oodinium ocellatum*.

The origin of the chromosomes is also different in *O. ocellatum* and *Noctiluca*. In the resting cell of the attached parasite, the chromatin is present in the form of very short, densely staining "threads." When the unattached individual takes in water, the nucleus and the cytoplasm both increase in volume. In such forms, the short "threads" apparently lose their ability to stain densely. In the prophase, long, thin and lightly-staining chromosomes are present. In later prophase and metaphase, the chromosomes are long, thick and more densely stained. In *Noctiluca*, according to Calkins (1899) and Ishikawa (1899), the chromatin is contained in large endosomes, which are referred to as chromatin reservoirs, each of which breaks up into a mass of chromomeres. These collect in chromosome strings or "chromospires." However, the "resting" nucleus of *O. ocellatum* is more like the condition found in the majority of the free-living dinoflagellates. In such forms as *Ceratium* and *Oxyrrhis* (see Lauterborn, 1895; Borgert, 1910 a and b; and Hall, 1925 a and b) the chromatin of the interphase nucleus is present not in the form of disconnected granules (as reported by Entz, 1921) but as chromomeres combined into distinct chromosomes. However, in certain of the recently detached stages of *O. ocellatum*, following the retraction of the polar processes, what appeared to. be disconnected granules were observed. Such an appearance was found only at this stage. Chatton (1920), on the other hand, reported that in *O. poucheti*, granular chromatin was present in young parasites and free-swimming dinospores.

In *O. ocellatum*, "centrospheres" containing diplosomes were often noted, especially in certain division stages of the palmellas. Similar centrioles were reported by Calkins for *Noctiluca* during metaphase and anaphase stages, and appeared to be the focal points of the mantle fibers. According to this investigator, "The centrosomes, possibly, come from the nucleus, where, during the resting stages, a small, deeply staining granule can be easily distinguished from the chromatin. This granule disappears during the early stages of chromosome formation." It later appears in the "sphere."

In *O. ocellatum* there is some evidence which indicates that the centrioles are not nuclear in origin, but rather arise from the black pigment portion of the ocellus complex. This is supported mainly by the fact that in living dinospores the flagellar apparatus is intimately associated with the red pigment bar of the ocellus, and in stained specimens, the diplosomes while still within the sphere were seen giving rise to the flagella. In early stages (just after retraction of the polar processes) two elongated bars with granules at each end were seen within a clear area in the posterior region of the body and strongly suggesting the appearance of the diplosome structure. In some cases, two diplosomes were found in the same region, each of which seem to be connected by fibers coming from the "sphere;" unfortunately this area was masked by numerous chromatoplastids so that

the details and relationships of these fibers to the sphere and the nucleus could not be determined. However, it may be pointed out here, as Calkins suggested, that it is very easy to mistake these centrioles for microsomes present in the same region. Ishikawa (1899) reported a single large centrosome for *Noctiluca*, much like the structure seen by Chatton (1920) for *Blastodinium*.

Ever since the early work of Kofoid and his students (Kofoid and Swezy, 1915 a and b, and Kofoid and Christiansen, 1915 a and b), the neuromotor apparatus of flagellates and its behavior during mitosis has received much attention. Jollos (1910) was one of the first to figure such an organelle for dinoflagellates. He showed that in *Gymnodinium fucorum* the apparatus consists of two blepharoplasts, two flagellar rhizoplasts passing from the blepharoplasts to an extra-nuclear granule, and a rhizoplast connecting the latter structure with the endosome. However, the behavior of this neuromotor system during mitosis was not traced. Chatton and Weil (1924) also reported a neuromotor apparatus for *Polykrikos schwartzi*. In this form two blepharoplasts were present, each of which gave rise to two unlike flagella. The blepharoplasts, in turn, were connected by rhizoplasts to granules of a "desmose" found just outside of the nuclear membrane. Here again, the complete behavior of this system of fibers was not followed. Hall (1925 a and b) showed that in *Oxyrrhis* and *Ceratium* the neuromotor apparatus was similar to that reported by Jollos, especially the one found in *Oxyrrhis*. This investigator (Hall), however, was able to follow the behavior of this system of fibers throughout division. He found that a typical paradesmose (centrosome-paradesmose type) was formed between two daughter centrosomes as they drew apart in the prophase and eventually disappeared in the late anaphase. However, just before the end of the prophase, the blepharoplasts disappear and each centrosome gives rise to new flagella. Entz (1928), from observations on living and stained material, found that in *Gonyaulax polygramma*, the flagella ended in two blepharoplasts, but no connection was observed with the centrosphere lying near the nucleus.

In the present material, no neuromotor apparatus was observed in the parasitic stage, although, as discussed above, a broad "flagellum" is present. During division "diplosome" centrioles within centrospheres are often found. In later stages of development (dinospores) these centrioles give rise to flagella. In living material the centrioles, together with their "desmose" and flagella, are intimately associated with the ocellus. Therefore, there is little doubt that the centrioles and the blepharoplasts are identical.

Although no definite paradesmose was observed in *O. ocellatum* during the early formation of the palmella, a paradesmose-like structure was observed in the late anaphase stage. Here, two sets of centrioles were present on both sides of the massed chromosomes. These centrioles were connected with each other by a long "desmose." In other words, this apparatus appears as a precociously developed paradesmose. Such a rapid division of the achromatic figure, however, has been previously reported. Thus, Ishikawa (1899) described and figured a division of the centrospheres in *Noctiluca miliaris* while the chromosomes were still in the late metaphase.

The centrioles in the present material are of the centroblepharoplast type and the central spindle can be considered analogous to a centroblepharoplast-paradesmose. Kofoid and Swezy (1921) consider the "sphere" of *Noctiluca* as a structure analogous to the centrosome-paradesmose of other flagellates. It is altogether possible, however, in view of the fact that the centrioles in this form have not been traced through the final development of the dinoflagellate, that this structure is similar to the one present in *O. ocellatum*. Chatton (1920) reported a centroblepharoplast in an uncer-

tain form of dinoflagellate (an anhang to an uncertain genus, *Atelodinium*) which he called "les spores a rostre." In these spores definite centrosomes were recognized at each pole of the mitotic figure. In later development, these granules gave rise to an aciculated structure which Chatton called a blepharoplast. However, one of his figures (pl. 17, fig. 193) shows a single flagellum, not connected with this elongated "blepharoplast." In 1921, Chatton reported centrosomes which have rise to flagella in the parasitic dinoflagellate *Syndinium turbo.*

SUMMARY.

Oodinium ocellatum Brown is recorded for the first time from the North American coast. The life-history has been redescribed and additional details, previously unobserved, are recorded.

The life-history includes the following stages: (1) the parasitic stage, a large pyriform organism anchored to the gill filaments of the host; (2) palmella stages, in which fission occurs, develop from the parasitic stage after it drops from the gill of the host; (3) flagellated dinospores; and (4) a typical peridinian stage, with girdle, sulcus, transverse and longitudinal flagella.

The parasitic stage is a large pyriform organism surrounded by a cellulose membrane. It possesses chromoplastids, amyloid granules, ocellus and an organelle of attachment composed of a peduncle, "flagellum," and fine rhizoid processes by which the parasite anchors itself to the gill filaments of the host. The ocellus is a characteristic morphological feature of this species. It is composed of a red or orange pigment bar connected to a thinner black pigment bar by means of minute fibrils. The space between the two is highly refractile, superficially appearing as a bar-shaped lens.

The parasite drops from the gill and immediately increases in size as a result of imbibition of water; the polar processes are retracted and the opening closed by a secretion of a cap.

Fission is initiated at the pole opposite to the peduncle and the first division is longitudinal. Just before each fission, erythrosomes or red pigment rodlets usually appear near the surface of the organism and then disappear at the end of division. The ocellus is usually lost when the erythrosomes are present and reappear when the rodlets disappear.

Under certain densities of sea-water and temperatures, the organism divides, giving rise to palmellas of 2, 4, 8, 16, 32, 64, 128 cells. The 128 cell stage divides once again to give rise to 256 free-swimming dinospores. Experimentally, it has been shown that specific gravity is an important factor concerned in the rate with which dinospores are formed. It also has been shown that dinospores may develop at the end of 8, 16, 32 or 64 cell stages and that this precocious development of flagellates is dependent in some degree upon the specific gravity of the sea-water.

The dinospores, when first released, are without a cellulose covering. In these forms, the neuromotor apparatus is part of the ocellus complex, each flagellum arising from a blepharoplast at one end of the black pigment bar, which acts as a "desmose." Later, these naked dinospores settle to the bottom, secrete a new cellulose covering and gradually metamorphose into a typical peridinian dinoflagellate with a girdle and sulcus. This typical dinoflagellate is the infective form.

In the transformation from the pelagic type to the sessile form found on the gills, the flagella are lost and the sulcus hollows out to form a cone-shaped area, the apex of which is later extruded. It is believed that the polar processes together with the "flagellum" are developed from this highly plastic sulcal region.

The vegetative nuclei of *O. ocellatum* are spherical or oval structures,

containing chromatin in the form of short, densely staining "threads." One or more endosomes may be present, but these structures do not take part in the division process.

When the parasites drop from the gills both the cytoplasm and nucleus increase in volume as a result of imbibition of water. The chromatin in these cells fails to stain densely.

A differentiated mass of cytoplasm is present, which in the attached parasites extends to the region of the peduncle. In these forms, many microsomes are found within this mass. In the unattached parasites, especially after rounding up has taken place, two granular cytoplasmic areas become evident and are connected with each other by means of a "canal." One is localized in the subnuclear region and eventually gives rise to the extra-nuclear spindle; the other is formed as a result of the disintegration of the polar processes after retraction.

During division, the achromatic mass or "sphere" elongates to form a central spindle. An interpretation is reported which may throw some light on the mechanism involved in the division of this spindle and the separation of the chromosomes.

Mitosis is of the paramitotic type. Two kinds of chromosome behavior were noted, one which takes place in the initial mitotic cycle and the other in palmellas after the 4 cell stage.

In the early stages of the first mitotic cycle, the chromosomes are present in the form of long, thin and lightly staining threads. The nuclear membrane disappears, and in later stages the chromosomes become thicker and more densely stained. At this stage they lie in parallel rows and at right angles to the elongated spindle. From the ends of the divided chromosomes, mantle fibers pass into the spindle and as the latter structure continues to elongate, the chromosomes are gradually drawn on the spindle and assume a metaphase "plate" appearance. There is no evidence that this "plate" encircles the extra-nuclear spindle as in *Noctiluca* and *Haplozoon*. The chromosomes continue to move to opposite poles and in early telophase maintain their parallel arrangement for a short time but eventually pass into the prophase of the next cycle. There is no evidence that a "resting" stage occurs at the end of division. In later telophase a thin nuclear membrane is reorganized, in some cases even before the spindle fibers are completely obliterated.

In the later palmella division (after the 4 cell stage), chromosomes typical of the early prophases of the initial cycle were not noted. Instead of lining up at right angles to the spindle, the chromosomes appear within the "sphere" as radiating V-shaped structures. It is assumed the V is the result of a unipolar splitting, and as the "sphere" elongates the chromosomes become straightened out to form the metaphase "plate." At this stage, presumably, the daughter chromosomes are separated by a transverse fission. In the telophase, no nuclear membrane is evident. In such forms, the chromosomes pass directly into the prophase of the next division.

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EXPLANATION OF THE PLATES.

PLATE I.

Camera lucida drawings of various stages in the life-history of living *Oodinium ocellatum*. x 950.

Fig. 1. Parasite recently detached from the gills of a host.

Fig. 2. Rounding up and the secretion of a cellulose cap. Note the erythrosomes.

Fig. 3. Stage showing the recession of the cell from the outer membrane. This is the anterior end and the point where fission will start.

Fig. 4. First division of a smaller individual. Note the stigma undergoing division.

Fig. 5. 16 cell palmella stage. Certain cells show the alignment of the amyloid granules prior to the formation of the dinospores.

Fig. 6. Naked dinospore. These forms are devoid of a cellulose membrane. The stigma-neuromotor complex lies at the posterior end of the cell.

Fig. 7. A new cellulose membrane is secreted. There is a space between the covering and the periplast, within which the free ends of the flagella eventually come to lie.

Fig. 8. Transformation of the dinospore to the typical dinoflagellate condition. The stigma-neuromotor complex is oriented so that the transverse flagellum lies in the girdle.

Fig. 9. This form shows the differentiation of the cytoplasm of the anterior region into a girdle and sulcus. The flagellar apparatus has begun to move anteriorly.

Fig. 10. Typical free-living *Oodinium ocellatum*.

PLATE II.

Camera lucida drawings of attached parasites. x 950.

Figs. 11-16. Corrosive sublimate fixation followed by iron-hematoxylin and Van Giesen's stain.

Fig. 11. Note the canal extending from the peduncle toward the center of the cell.

Figs. 12, 13. Note the ring in the peduncle. This structure stains yellow with Van Giesen's. Note the "microsomes" within the differentiated mass of cytoplasm.

Fig. 14. Section of a large parasite showing the chromoplastids. Note the densely staining structures within the plastids some of which indicate division.

Fig. 15. Young parasite.

Fig. 16. Section of a parasite through the "sphere." Note the plastids.

Figs. 17-20. Zenker's fixation followed by iron-hematoxylin and eosin.

Fig. 18. Section at the level of the nucleus, showing the short interphase chromosomes.

Fig. 20. Individual showing the pseudo-flagellum. Note the radiating arrangement of the chromomeres.

Figs. 21-24. Zenker's fixation followed by Mallory's triple stain. In these forms the chromoplastids, ring and microsomes stain red; the cellulose wall and the edge of the plastids a deep blue, while the amyloid granules take on a lighter blue color.

PLATE III.

Camera lucida drawings of detached parasites. x 950. Bouin's fixation followed by Delafield's hematoxylin and counterstained with eosin.

Fig. 25. Detached parasite after a certain amount of swelling has occurred as a result of imbibition of water. Note the chromatin in the form of distinct granules. The peduncle and the rhizoids are slightly retracted.

Fig. 26. Note the elongation of the endosome. The structure, however, does not take part in the nuclear division of this species. The "sphere" may be seen just posterior to the nucleus.

Fig. 27. Typical detached parasite. Note the canal extending from the peduncle to the "sphere" mass.

Fig. 28. Early prophase. The "sphere" mass in this individual is cup-shaped.

Fig. 29. Early prophase. The nuclear membrane has disappeared and the "sphere" shows some elongation.

PLATE IV.

Camera lucida drawings of mitosis in *Oodinium ocellatus*. x 950. Material fixed in Zenker's and stained with iron-hematoxylin.

Fig. 30. Early prophase. The nucleus has elongated, but the chromosomes are still in the shortened phase. Note the "diplosome" in the center of the sphere and the scattered microsomes.

Fig. 31. Early prophase. The chromosomes begin to show their parallel arrangement. The nuclear membrane next to the sphere has disappeared and distinct mantle fibres can be seen passing from the nucleus and converging towards the center of the sphere.

Figs. 32-34. Early prophases. These stages are not completely understood as yet. In Fig. 32, the nucleus is a bilobed structure with both lobes extended upwards; the chromosomes are parallel to each other and mantle fibres can be distinguished. The sphere shows what appears to be the beginning of the protoplasmic strands. In Fig. 33 the nucleus shows a still further separation although the sphere has not begun to elaborate as yet. This Figure and Fig. 34 might indicate that the nucleus is forming a C-shaped structure somewhat like that in *Noctiluca*. However, no trace of the part between the ends could be found.

Fig. 35. Late prophase. The chromosomes thicken and elongate considerably. The sphere has begun to elongate. In this form a remnant of the nuclear membrane is still present, although usually when the chromosomes have reached this stage the nuclear membrane is entirely lacking.

PLATE V.

Camera lucida drawings of mitosis in *Oodinium ocellatum*. x 950. Material fixed in Zenker's and stained with iron-hematoxylin.

Fig. 36. Late prophase. The chromosomes are being drawn upon the central spindle which is formed as the sphere divides further and further.

Fig. 37. Slightly earlier stage than Fig. 36.

Figs. 38, 39. Prophase. Many forms were encountered with this sheaf-like formation of the nucleus.

Fig. 40. Late prophase. Superficially this figure appears as a metaphase stage but actually the chrosomes have not begun to migrate onto the spindle. Note the diplosome centrioles to which the mantle fibres can be seen converging.

Fig. 41. Metaphase. The chromosomes are aligned on the central spindle. The final separation has just started in the form represented in Fig. 42.

Fig. 43. Telophase. The chromosomes have shortened and cell division has occurred. The daughter nuclei are still connected by the remains of the central spindle.

PLATE VI.

Camera lucida drawings of mitosis. Zenker's fixation followed by iron-hematoxylin stain. x 950.

Figs. 44, 45. Early and late anaphase. Note the central spindle fibers.

Figs. 46, 47. Telophase. In Fig. 47 the daughter nuclei are still connected by the remains of the central spindle and a thin nuclear membrane is reorganized round each nucleus.

Fig. 48. Late telophase. Reorganization of the daughter nuclei has occurred and the "sphere" mass once again reappears in the subnuclear region.

Fig. 49. 4 cell stage. Note centrosphere with diplosomes and V-shaped radiating chromosomes in two of the cells. In the two cells to the right, the separation of the chromosomes has occurred, presumably after the V's have straightened out.

PLATE VII.

Camera lucida drawings of nuclear division.

Fig. 50. Early anaphase. 4 cell stage. After the chromosomes are arranged upon the central spindle, a transverse separation occurs and the migration to the opposite poles begins.

Fig. 51. Anaphase. Note the processes passing from the poles of the sphere to the periphery. These processes bifurcate and at the forks of the bifurcations may be seen a small densely staining granule.

PLATE VIII.

Camera lucida drawings of mitosis in *Oodinium ocellatum.* x 950. Stages showing the V-shaped radiating chromosomes. Note the centriole in Fig. 52.

Fig. 53. Early telophase. The figure to the right is an optical section showing a paradesmose (?).

Fig. 54 shows a divided "desmose" in the posterior part of the cell.

Fig. 55 shows two diplosomes to which mantle fibers (?) converge.

PLATE IX.

Camera lucida drawings of dinospores. x 950. Zenker's fixation and iron-hematoxylin stain.

Figs. 56-74. Metamorphosis of *Oodinium ocellatum* to the free-swimming dinoflagellate stage.

Figs. 56-62. Dinospore prior to the final division.

Figs. 56-58. Late telophase.

Fig. 59. Note peculiar spiral formation of the cellulose membrane.

Figs. 60-63. Flagellation.

Figs. 64-66. Note the flagella growing out from the diplosome.

Fig. 67. Orientation of the neuromotor apparatus. Note cytoplasmic differentiation which eventually will form the girdle and the sulcus.

Figs. 68-70. Various forms showing different stages and appearance of the neuromotor apparatus.

Fig. 71. Neuromotor apparatus torn from the cell. Note the blepharoplasts and the connecting desmose.

Figs. 72-74. Cytoplasmic differentiation resulting in the development of the girdle and sulcus. Note the migration of the neuromotor apparatus to its final point in the sucal-girdle junction.

Fig. 75. Stage in the transformation from the free-swimming dinoflagellate to the parasitic type. In this form the sulcus has developed into a cone-shaped structure, the tip of which protrudes through an opening in the cellulose cell wall.
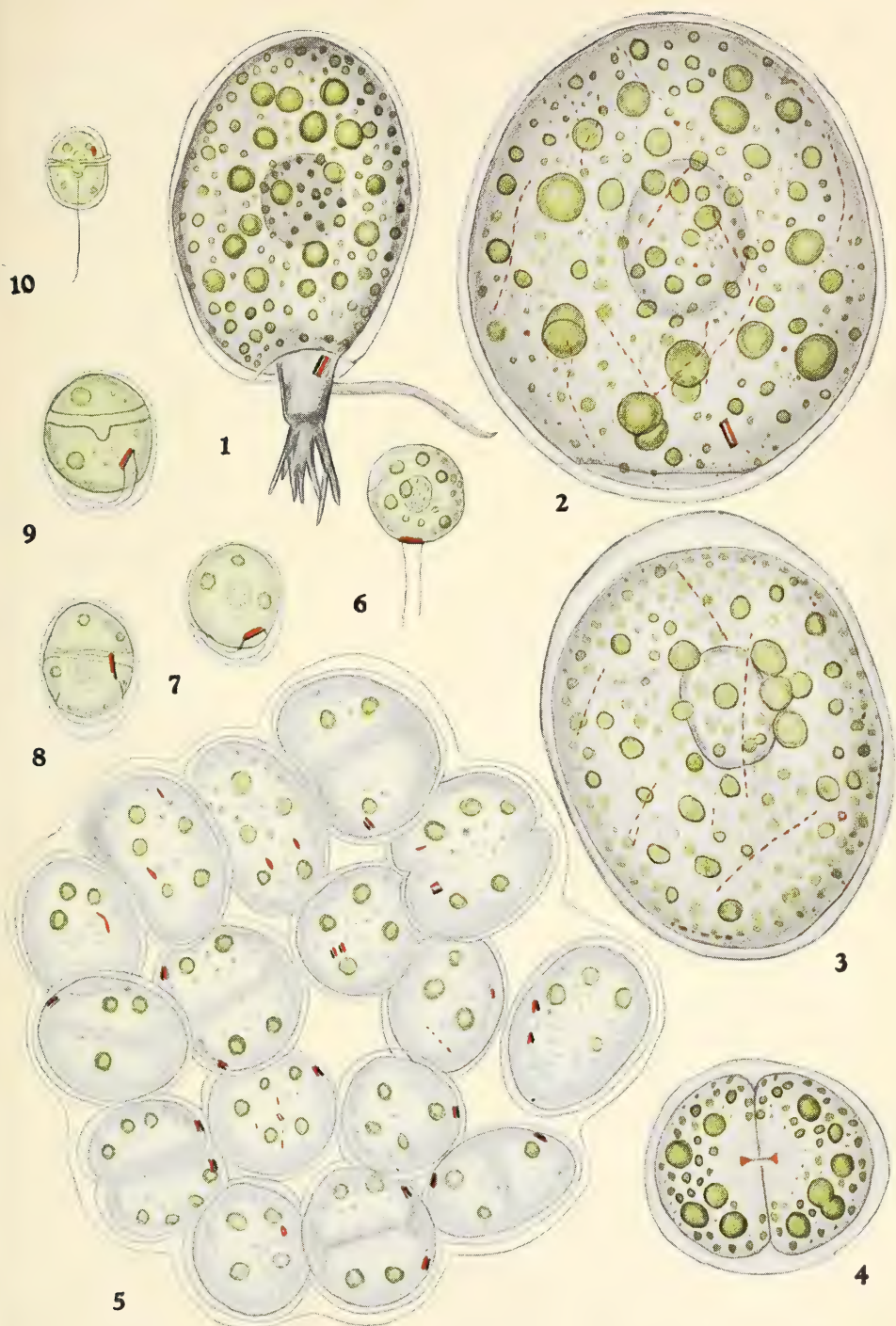
CAMERA LUCIDA DRAWINGS OF VARIOUS STAGES IN THE LIFE-HISTORY
OF LIVING OODINIUM OCELLATUM.

PLATE II.
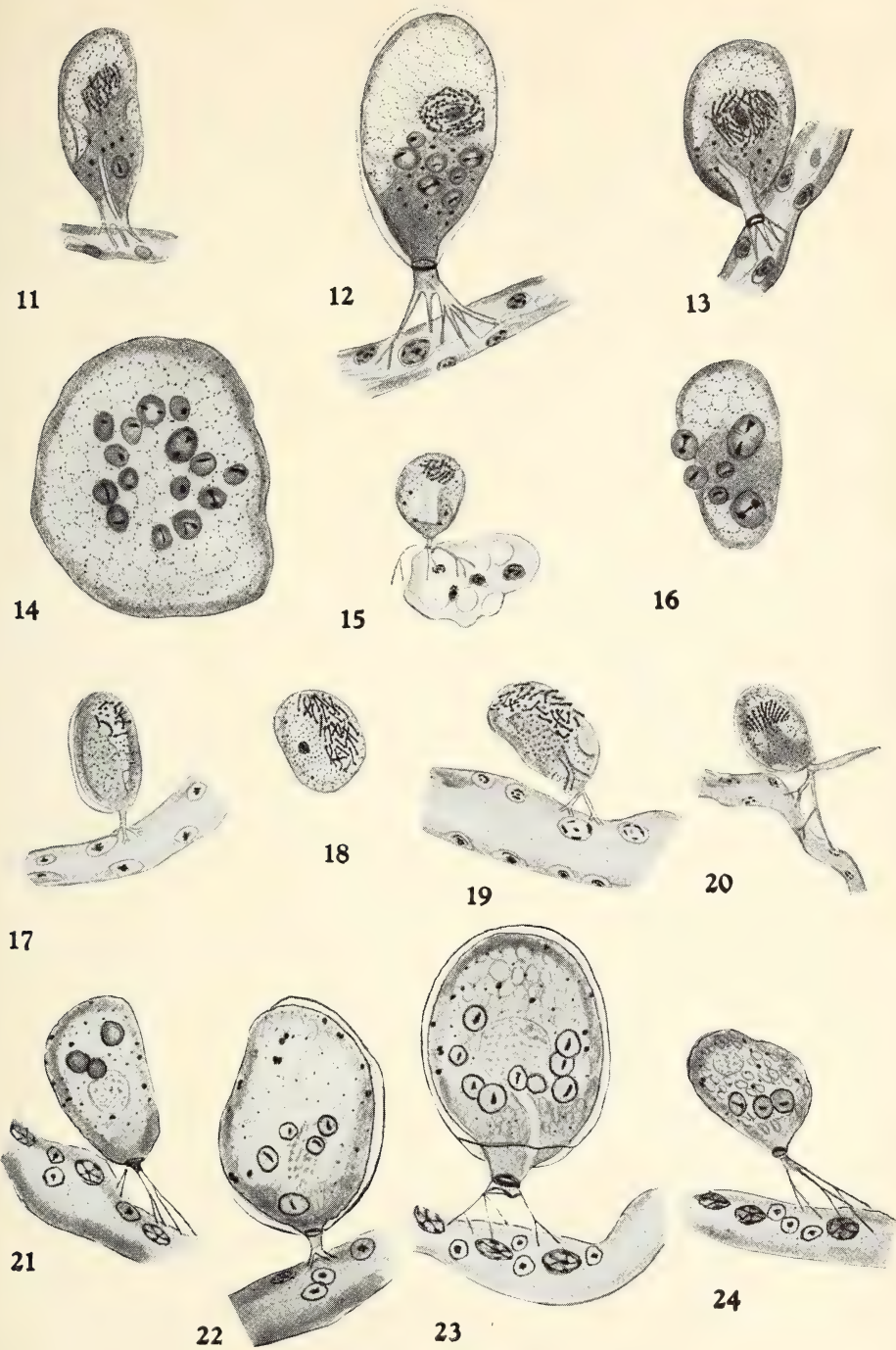
OODINIUM OCELLATUM. CAMERA LUCIDA DRAWINGS OF
ATTACHED PARASITES.
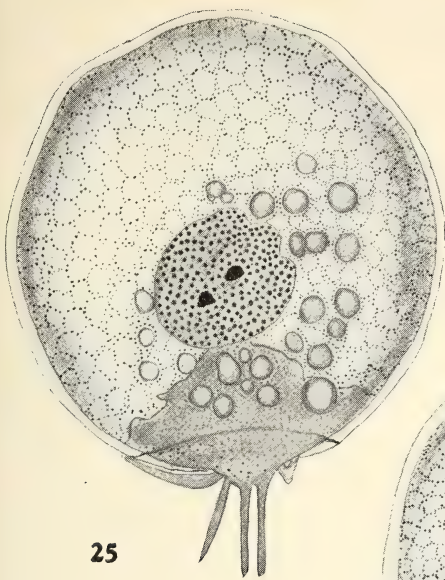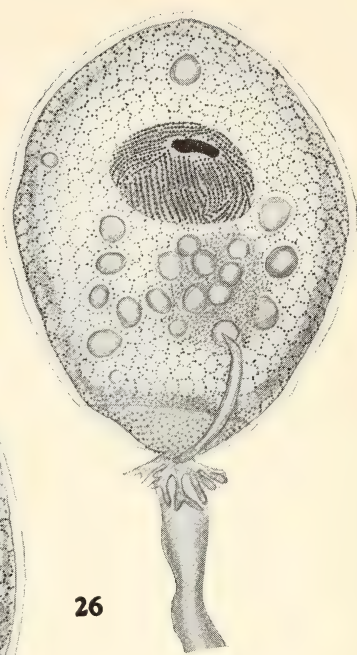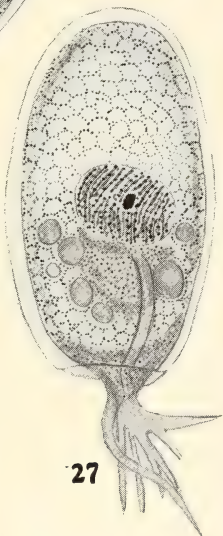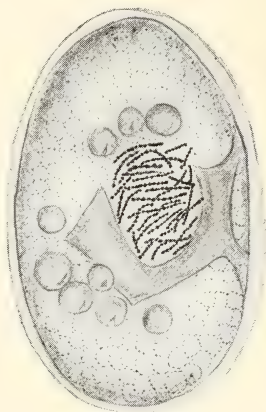
OODINIUM OCELLATUM. CAMERA LUCIDA DRAWINGS OF
DETACHED PARASITES.

CAMERA LUCIDA DRAWINGS OF MITOSIS IN OODINIUM OCELLATUM.
MATERIAL FIXED IN ZENKER'S AND STAINED WITH IRON-HEMATOXYLIN.

PLATE V.
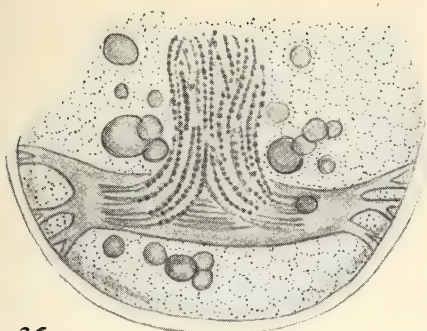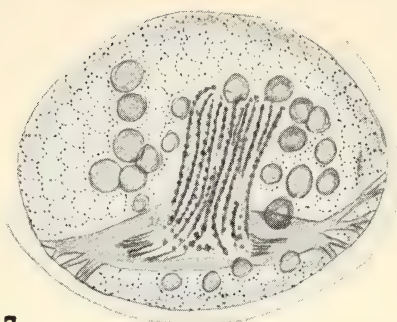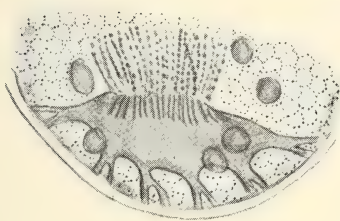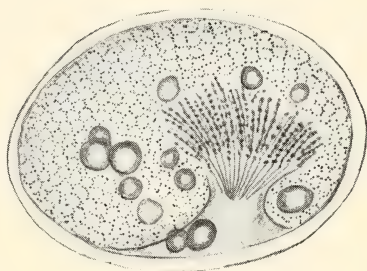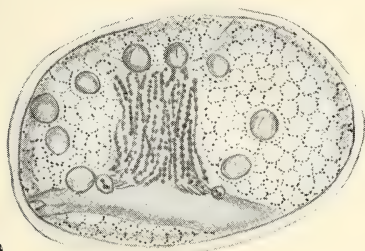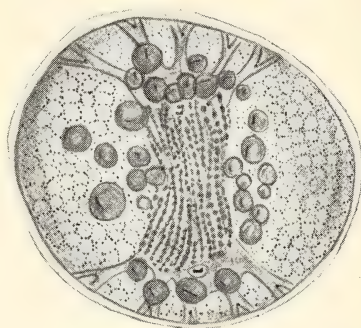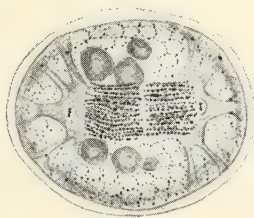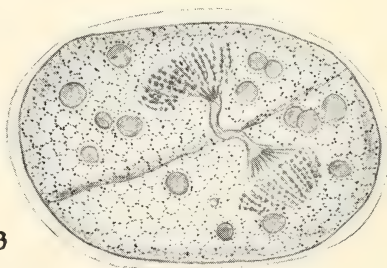
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MATERIAL FIXED IN ZENKER'S AND STAINED WITH IRON-HEMATOXYLIN.
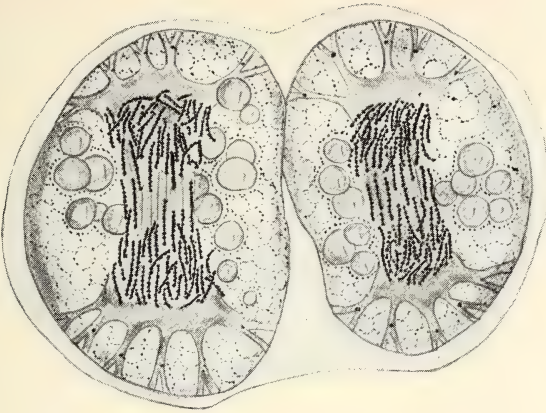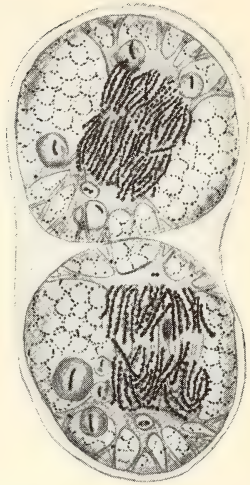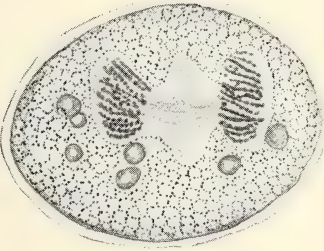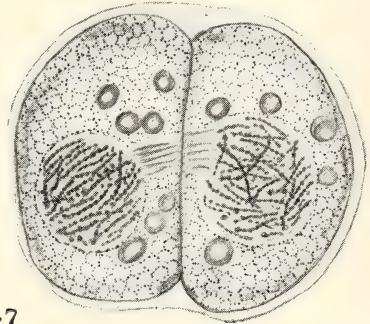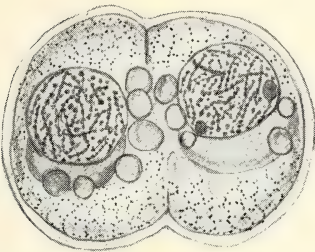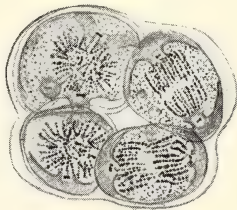
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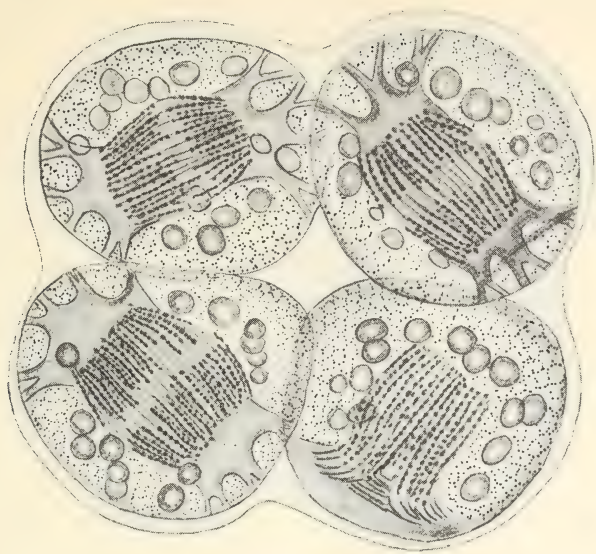
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OODINIUM OCELLATUM. CAMERA LUCIDA DRAWINGS OF NUCLEAR DIVISION.
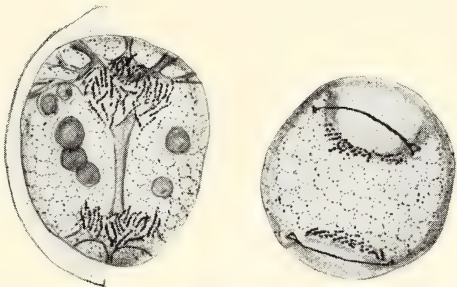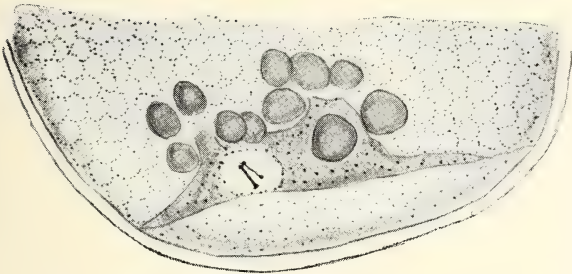
CAMERA LUCIDA DRAWINGS OF MITOSIS IN OODINIUM OCELLATUM.
STAGES SHOWING THE V-SHAPED RADIATING CHROMOSOMES.
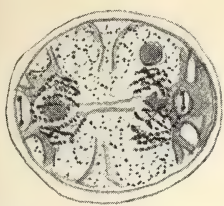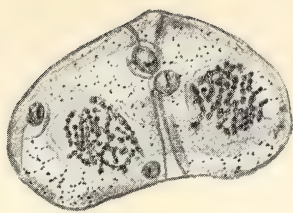
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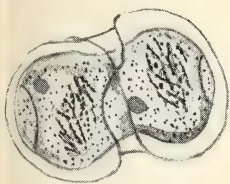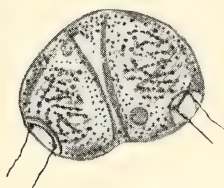
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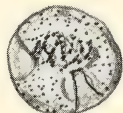
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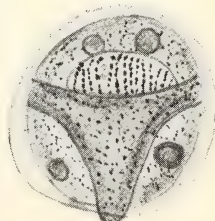
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OODINIUM OCELLATUM. CAMERA LUCIDA DRAWINGS OF DINOSPORES.
ZENKER'S FIXATION AND IRON-HEMATOXYLIN STAIN.

13.

The Winter Movements of the Landlocked Alewife, *Pomolobus pseudoharengus* (Wilson).

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&

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(Text-figures 1-6).

Complaints by householders in New York City of small fishes emerging from their faucets, led Mr. Herman Forster, Deputy Commissioner of the Department of Water Supply, Gas and Electricity, to inquire at the New York Aquarium concerning the possibility of control of these free but unwelcome fishes, see Forster (1935). In order better to understand the problem, a study was undertaken of the conditions reported by him. The fishes were found to be typical landlocked specimens of *Pomolobus pseudoharengus* (Wilson), Text-fig. 1. The data subsequently accumulated uncovered certain features of the behavior of these fishes not hitherto understood and are presented herewith. This study was possible because of certain peculiar features of the environment, due to its being part of the municipal water supply system, added to the cooperation of the Department.

Shortly after the work was undertaken a paper on this same species, Odell (1934), reached our hands, which covered a considerable portion of the ground we had originally planned to include. In view of this and the fact that the New York State Conservation Department Biological Survey was to cover our territory in its 1936 work, we abandoned all but such parts of the original plan that seemed to be complementary to the work of Odell. There is otherwise a marked dearth of papers on this species and since Odell has indicated their contents it is not necessary to refer to them here, especially since their bearing on present problems is slight. Specifically, Odell had no data on the whereabouts of his fish during the winter months and wrote: "In summer it is wide-ranging in habit, having been taken at all depths down to 160 feet. The winter distribution is unknown." Fortunately it is exactly this latter time which is covered best by our data.

It is during this period that *Pomolobus* appears in the drinking water. During certain years great quantities may be taken from the protective screens which cover the outlet of Kensico Reservoir—the lake which forms the habitat of these fishes. The outlets here referred to drain at a depth of from 30 to 60 feet from the surface. No regular records of the fish on the screens had been kept, which were suited to our studies, but it was a relatively simple matter to have the file of complaints in the Water Department office examined for a period of years. For this information and for permission to use it, we are indebted to Mr. Forster. The data covering

eleven years are given by months in Table I. Actually these figures represent all complaints of fish in the water supply, but other species, such as *Perca flavescens* and *Anguilla rostrata*, are so rare as to be negligible. The mean for the eleven-year period shows a very definite peak in October, see Text-fig. 2. Observations made on the screens in 1936 and the fragmentary data of other years at that place show the peak of fish on the screens to occur in February or March. This suggests that the small fish drop down first, or at least scatter out sooner, for they do not appear on the screens until the larger fish form a mat for them to rest against. Since *Pomolobus* is in more or less evidence at the upper end of this lake from about May to September and is not to be found near the outlet until the end of that period, it would clearly seem to follow that there is an autumn movement downstream of both large and small fishes.
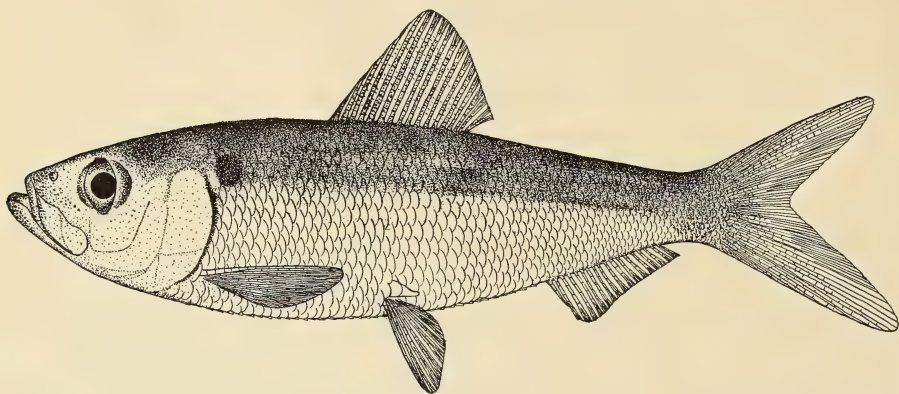
Text-figure 1.

The landlocked Kensico Reservoir alewife, locally called sawbelly, *Pomolobus pseudoharengus* (Wilson). A typical example of the year's hatch, 51 mm. standard length, Aug. 23, 1935. Fishes this size and smaller sometimes are found in the municipal water distribution system. (Drawing by Ralph Graeter).

If the number of complaints are plotted by years, as in Text-fig. 3, it becomes evident that there is a wide divergence from year to year in their quantity. Varying economic or political events may be expressing themselves here to some extent—a difficulty not inherent in the treatment of Text-fig. 2, which uses the mean value for a number of years. However this may be, it cannot invalidate the effect of the fishes themselves, the data of which also agree with the memory of workers in the Water Department. In other words there were many *Pomolobus* on the screens in 1926 and greater numbers than ever before were noted on them in 1934 and 1935. The period between these two peaks of abundance as thus measured comes to eight years.

It was impossible to obtain non-selected samples from the screens as to number and size. An unknown number of small fish slipped through the meshes, so that it was not possible even to guess at the quantities or the size composition of the *Pomolobus* that passed the ⅝-inch mesh of the screens. Text-fig. 4 gives some idea of the screens and the fishes removed from them. The screens were removed and cleaned irregularly, according to the quantity of fish collected on them, but the records were of such a nature that statistical analysis was not possible.

TABLE I.

Written complaints to the New York City Water Department of fishes in the water supply, by months for eleven years.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1925......	..	..	..	..	..	..	..	..	..	..	2	..	2
1926......	..	..	..	..	..	..	..	..	13	4	2	..	19
1927......	..	..	..	..	..	..	1	..	1	..	..	2
1928......	..	..	..	..	2	..	..	..	..	..	..	..	2
1929......	..	..	..	..	..	..	..	..	..	1	..	..	1
1930......	..	..	..	..	..	..	..	..	..	..	1	..	1
1931......	..	..	..	..	..	..	..	..	1	..	..	2	3
1932......	..	..	..	..	..	..	..	..	..	..	..	..	0
1933......	..	..	..	1	..	..	..	..	..	2	..	..	3
1934......	..	..	..	..	..	..	..	..	40	61	8	6	115
1935......	..	..	..	..	..	..	..	..	..	49	..	..	49
TOTAL...	0	0	0	1	2	0	0	1	54	118	13	8	197
Mean.....	0	0	0	.09	.18	0	0	.09	4.91	10.72	1.18	.73	17.9

During the winter of 1935 a large number of samples was taken from the screens and these were measured and sexed. While this gives a fair idea of sizes in each group, it cannot be considered a measure of relative
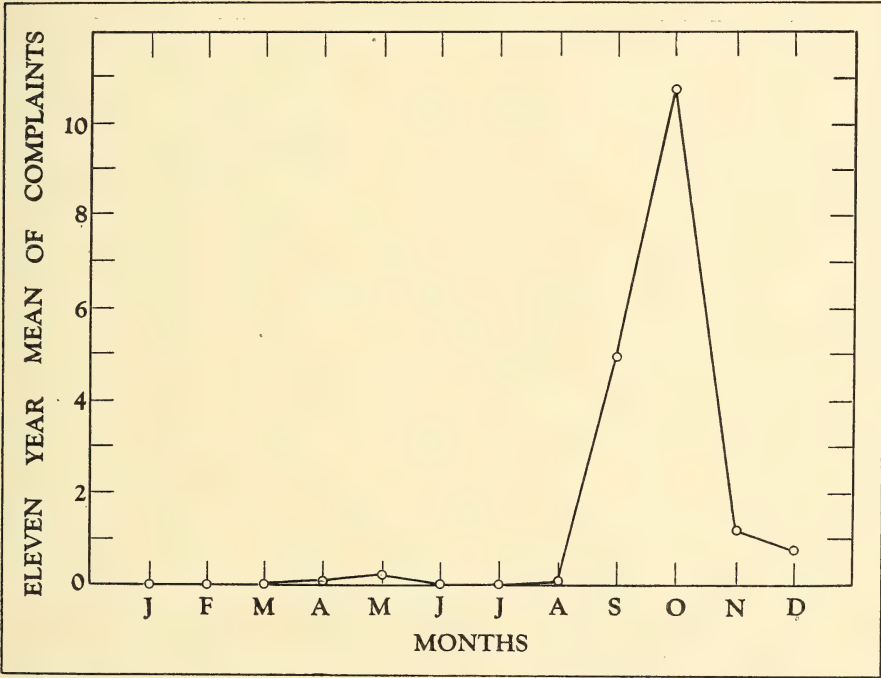
Text-figure 2.

Complaints of fishes emerging from taps made to the New York Department of Water Supply. Mean values by months for eleven years from 1925 to 1935 inclusive.

quantities of old and immature fish. Although the samples were random ones, these were already highly selected piles of fish as cleaned from the screen. This does not apply to the sex ratios of the adults, however, as the separation of males from females, in point of size, was so slight that a mechanical selection on this basis was out of the question. Bearing this out is the fact that distribution curves, not published, were found to be quite symmetrical and that the much smaller young were taken regularly. Table II gives these figures.

It will be noted that the sex ratios in the last column of Table II show a remarkable amount of variation. Apparently this is not accidental, since it follows a well-marked rise and fall as shown in Text-fig. 5. It would seem that the schools being caught on the screen varied in their sex composition in some regular manner. The various interpretations that may be placed on this phenomenon will be discussed subsequently, as will the nature of the 1936 sample.

During the late summer and fall large quantities of young fish are to be found at the upper end of Kensico Reservoir at a point where the flume from the Catskill watershed enters. A measured sample of these showed a mode at 4 cm., see Table II and Text-fig. 1. Scales of these specimens showed no winter ring but were entirely uniform in structure, as would be expected. The larger fish taken on the screens had been almost uniformly scaled by the tremendous washing they received, making adequate age analysis by this method impossible. However, such scales as could be found showed that the mean position of the first winter ring exceeded the August mode of 4 cm., and fell below the early spring mode of 5 cm., see Table III and Text-
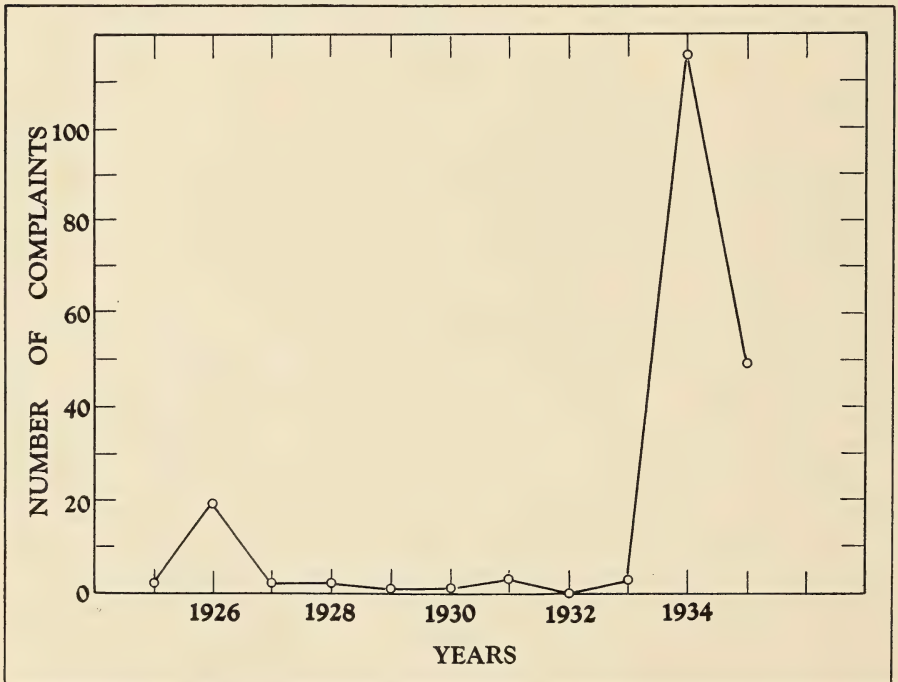
Text-figure 3.

Complaints of fishes emerging from taps made to the New York Department of Water Supply. Total number of complaints per year for eleven years from 1925 to 1935 inclusive.

fig. 6. The interpretation of these data would seem to indicate the following:

The fishes, very much in evidence during the summer months, principally in the upper half of the lake, disappear from there as the water cools. At the same time some of the smaller ones, of the same year, emerge from household taps, while later the larger sizes catch on the coarse protective screens along with smaller sizes caught only because of the restricted openings induced by the larger fish. The peak of the movement of the year's fishes measured by observations of the workmen who are charged with the care of the screens, and the records of water consumer complaints, is during October and reaches chiefly from September to December. The larger and older individuals appear in their maximum numbers in February or March.

TABLE II.

Sizes and states of *Pomolobus pseudoharengus* taken from the screen at the outlet of Kensico Reservoir.

1935	Female				Male				Immature				Total	Sex Ratio
	No.	Max.	Mode[1]	Min.	No.	Max.	Mode	Min.	No.	Max.	Mode	Min.		
Feb. 15–16	109	12.3	11	9.5	18	13.5	10	9.5	115	7.0	5	3.5	242	6.4
Feb. 22....	70	12.7	10	9.5	4	10.5	10	9.0	100	6.8	5	3.7	174	17.5
March 1...	26	12.0	10	9.2	2	9.5	9	9.3	95	8.2	5	3.4	123	13.0
March 18..	7	12.0	11	10.5	5	11.0	10	9.0	2	5.5	5	5.0	14	1.4
April 8....	39	13.5	11	10.0	24	11.5	11	9.5	1	..	7	..	64	1.6
April 22...	41	12.2	10	9.4	4	12.0	10	10.0	20	6.4	5	5.0	65	10.2
May 6.....	29	11.7	10	9.5	6	11.4	9	9.0	99	6.5	5	3.7	134	4.8
May 20....	7	12.0	11	10.5	3	11.0	10	10.0	0	..	..	..	10	2.3
1936														
Feb. 19....	12	14.0	12	10.0	9	13.2	9	9.0	3	5.0	5	4.5	24	8.9
Total......	340	..	..	..	75	..	..	..	435	...	..	..	850	..
Extremes..	..	14.0	..	9.2	..	13.5	..	9.0	..	8.2	..	3.4	..	..
Means.....	..	12.5	10+	9.6	..	11.5	10—	9.3	..	6.5	5+	4.1	..	4.5
1936	Fishes collected by seine in upper Kensico.													
Aug. 17....	..	..	..	..	..	..	..	..	300	6.0	4	2.6	300	..
Aug. 23....	..	..	..	..	..	..	..	..	64	6.3	4	3.6	64	..
Total fish examined.. 1214														

[1] The modes as used throughout this paper were picked from distribution curves of 1 cm. intervals. Extremes measured to the nearest mm. All measurements are in cm. and refer to standard lengths.

If these fishes are to be considered a recently landlocked form of the sea run *Pomolobus pseudoharengus*, it should seem that the fishes are merely acting according to their normal anadromous nature. There are, however, several reasons to question this close kinship between the two on the basis of observed habits. Spawning of the sea run *Pomolobus* occurs early in the spring in local waters. At Swimming River, New Jersey, for example, the spawning fish arrive from the last week in March to the middle of April. The old fish disappear about the middle of May. These fish have

passed three or more winters. The males range from 22.2 to 27.3 cm. standard length and have a mode at about 24.2, while the females range from 24.2 to 27.3 cm. with a mode at about 26.0. This is based on a sample of 50 fish taken in 1923, in part discussed by Nichols and Breder (1926). In tributaries of the Hudson River at Troy, New York, Greeley (1935) observed spawning fish in the middle of May at a temperature of 52° F. This is considerably north of our locality and the slight difference in time is to be expected. The sizes of these fish are not given. Since the adult Kensico Lake fish do not appear on the screens until February there is certainly no downstream migration until much later and, supposedly, spawning is much later, on a considerably warmer temperature. Odell, at Seneca Lake, obtained his eggs from late May to mid-August. Of course this may be only the immediate influence of environment, but one would hardly expect such a difference in temperature thresholds. The whirling splash of the spawning fish described by Greeley is apparently identical to that of the landlocked form.

Text-figure 4.

A typical mass of *Pomolobus* removed from a screen at the Kensico outlet, March 2, 1935.

Concerning the wide differences in numbers coming from the lake (Table II and Text-fig. 3), there is one item that may be used to question this downstream migration. It has long been known that periodically there are heavy mortalities among these fishes in certain lakes and at such times windrows of dead fish may collect along the lake shores. Such a condition has never been noted in Kensico and it may be possible that due to its form, rate of flow, or other factors, fishes in a weakened and dying condition, which might otherwise strew the shore line, gravitate to the outlet screens. Since there was a period of eight years between outbreaks, it more or less suggests the population cycles common to so many organisms.

Another way to look at this would be to assume that only on an occasional year did a very successful spawning take place and that the heavy coating of the screens with fishes in 1934 represented the peak of the death

rate of some earlier but peculiarly successful year class. Since our fish showed modes between 9 and 11 cm., it may be that most of them had passed through four to six winters, which would place the successful hatch between 1929 and 1931, as suggested by Table III. Supporting this are the data from the screens in 1936. The mode and range of the females exceed anything in 1935, whereas the young and males are typical of the preceding year. If these females represent the residue from the previous year of that abnormally successful year class, such figures would be expected. Since the males of such fishes frequently mature a year earlier than the females, it would not be surprising to find few left. It may be noted that these 1936 males cover the full spread of variation found in the entire 1935 collection. The relatively few fishes in the 1936 collection can scarcely be considered as invalidating these views, since the 1935 material is remarkably uniform and the mode of the 1936 collection closely approximates the extreme size of females for the previous year—a type of selection almost impossible to make artificially, especially in view of the constant size of the males.

TABLE III.

Comparison of Seneca Lake *Pomolobus* with growth from indications of scale marks on Kensico Lake specimens.

Annulus	SENECA LAKE[1]		KENSICO LAKE	
	Female	Male	Female[2]	Male[3]
1	5.5	5.5	4.3	4.7
2	12.1	11.4	6.7	7.4
3	12.5	12.1	7.8	8.2
4	13.4	13.9	9.1	9.2
5	13.9	14.0	10.8	10.5
6	....	....	11.1	....
7	....	....	12.0[4]	....

[1] Data from Odell (1934) ; mean values of his Table I.
[2] Mean of 5 females.
[3] Mean of 3 males.
[4] Scale edge in early spring = actual standard length. All measurements in cm. standard lengths.

As noted in another connection, scale examination from these screen-caught fish was not satisfactory, but all examined appeared to be in their fourth year or over. Adventitious and, perhaps, spawning rings were found so confusing that on the basis of our scant material it would be unwise to attempt a close analysis of these data. There are, however, two pertinent points that emerge. One is that there seemed to be no appearance of second or third year fish on either a basis of modes or scale examinations. In the latter the mean value for the second winter was 6.7 cm. female and 7.3 cm. male. Compared with Table II it is clear that this is close to the extreme maximum of size for immature fish and just where there were exceedingly few individuals taken—the upper end of the distribution curve; likewise the third ring with mean values at 7.8 cm. female and 8.2 cm. male. It is not until the fourth annulus is reached with mean values at 9.1 cm. female and 9.3 cm. male that the minimum values of the mature fish of Table II are reached. Although these scale data are fragmentary, it is clear from the measurements of the fish that some classes, which lie between the young of the year and the smallest adults obtained, are practically or completely absent. If all classes had been present on the screens, with the annuli falling where they do, no such clear separation, as indicated

by Table II, could be possible. Furthermore, immature, male and female groups showed sharp peaks to their very symmetrical distribution curves. The immature fish from the screens (Table II) show a single annulus near the edge of the scale, as of course they should.

The other evident item is the relatively slower growth of our fish as compared with Odell's. No matter what age be ascribed to our fishes, making allowance for the misinterpretation of adventitious or spawning marks, none reached the sizes he obtained. Our tentative values as compared with his are given in Table III and in Text-fig. 6. These fish do not reach the modal sizes his did when laying down their third winter ring. The Kensico fish, on this basis, have an extremely rapid growth before the first winter and then slow down gradually. Odell's material, on the other hand, shows materially faster growth, including the second season. Lest it be thought that we merely missed the first annulus, it may be pointed out that the scales from the fish collected by net in August were carefully examined and showed no ring, whereas those slightly larger, taken in the screens in spring, showed one most clearly. This agreed in position with the first ring on the scales of the larger fish. It is possible that this difference in growth rate between Seneca and Kensico fishes may be associated with a temperature
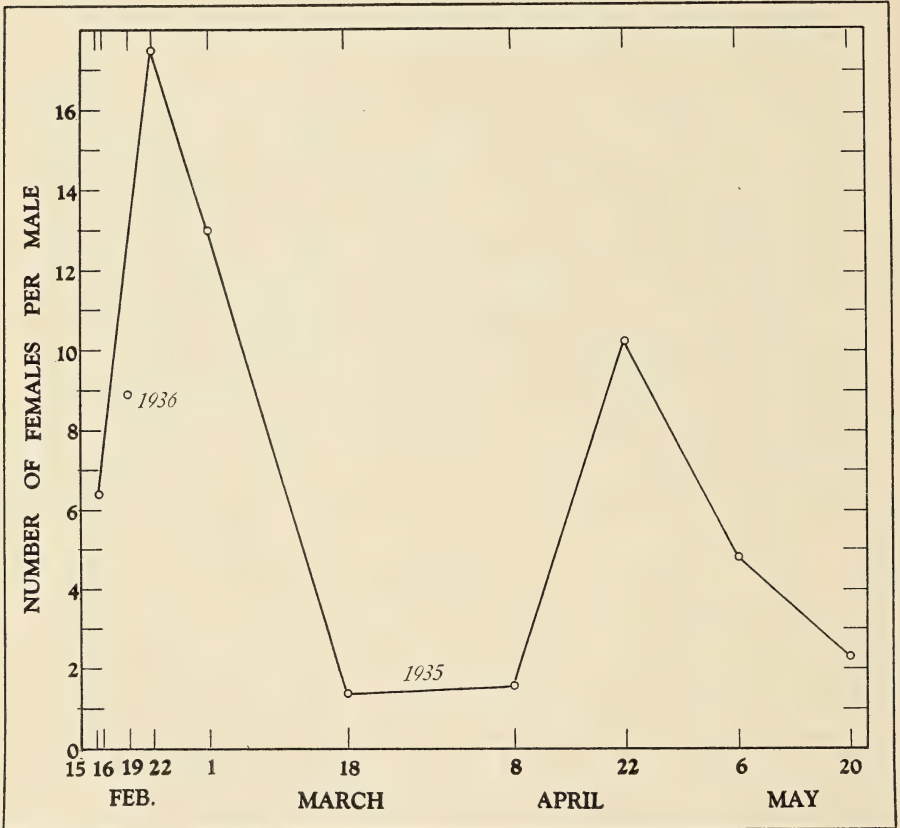
Text-figure 5.

Sex ratio by dates of samples of *Pomolobus pseudoharengus* caught on the screens at Kensico Reservoir during 1935 and one for 1936. The figures in the vertical index represent the number of females divided by the number of males present.

differential, but on this point we have no comparative data. The water delivered to Kensico Reservoir is treated with alum and soda ash before it reaches there and sometimes copper sulphate is used in the lake. The alum is precipitated in the upper part of Kensico. See Hale and Dowd (1917) for a discussion of the chemical and physical conditions in this lake, including a discussion of the thermocline which they found forming at between 16 to 23 feet. Later data indicate that it is apt to form at between 20 and 30 feet. This chemical treatment should have a depressing effect on the plankton and it may be that at times when the species is numerous a starvation dwarfing ensues. It is pointed out in this connection that the fishes taken on the screens were entirely empty of identifiable remains. However, there may be a complete cessation of feeding at this time of year. The fish of the year taken by other means were found to contain microcrustacea only. Although no effort was made to study this feature in detail, it agrees well with the data of Odell, for in August, the month of capture of these fish, he reported the stomach contents as 90% microcrustacea. He does not give the size of his fishes, but in a personal communication he stated that there was no feeding differential to be noted with different size groups.

Regarding the physical conditions, it may be mentioned that temperatures in Kensico ranged in 1935 from a mean of 63° in August to 34° in February. Thus the young fish began to appear in the faucets just after the summer peak of temperature was passed (Text-fig. 2) and the adults reached their maximum congestion on the screens about coincident with the lowest winter temperature. According to the Water Department records, the pH has been slowly dropping since 1930 when the average was 6.9, whereas in 1935 it had reached 6.7, which figure it had shown since 1933. We are unprepared to draw any inferences from these data, if indeed they have any important bearing on the fish under consideration.

The variation in sex ratio expressed in Table II and Text-fig. 5 is difficult of interpretation, but probably has to do with a differential movement of the sexes in regard to their spawning beds. The females markedly exceed the males in number in late February and again in late April. If this species possesses a 1 to 1 sex ratio it would seem that the males are more generally successful in avoiding disaster on the screens, which in turn would indicate less of a tendency to drop downstream. Just why this should be most marked in February and again in April is not at all clear at this time, unless the females descend to the screens at a faster rate after they are once started, and remain longer after the males move upstream. Because of the virtual failure of the fish to appear on the screens in 1936, a continuance of this study was impossible. We question the validity of the apparently more rapid growth of the males, as based on scale examination, preferring at this time to consider it as probably due to the small number of fish involved. Likewise, corrections for Lea's phenomenon, as given by Odell, would be pointless in connection with our material, because of the relative coarseness inherent in these figures based on so few fishes.

Young fish of the year showed a modal length of 4 cm. in the latter part of August, which reached 5 cm. before the cold weather checked increment, as indicated in Table II. If it is true that a successful spawning occurs relatively rarely, it may be that intermediate classes drop out and all those of the immature class measured by us were doomed to an early demise. At least it is difficult to conceive how otherwise to account for the condition and sizes of fish caught on the screen in 1936.

The items here discussed necessarily lead one to infer that these violent epidemics of *Pomolobus* in Kensico Lake belong with that great group of periodical fluctuations of animal populations and that, other conditions remaining static, a return of large numbers should not be expected for some little time, perhaps for a period somewhat approximating that of the last
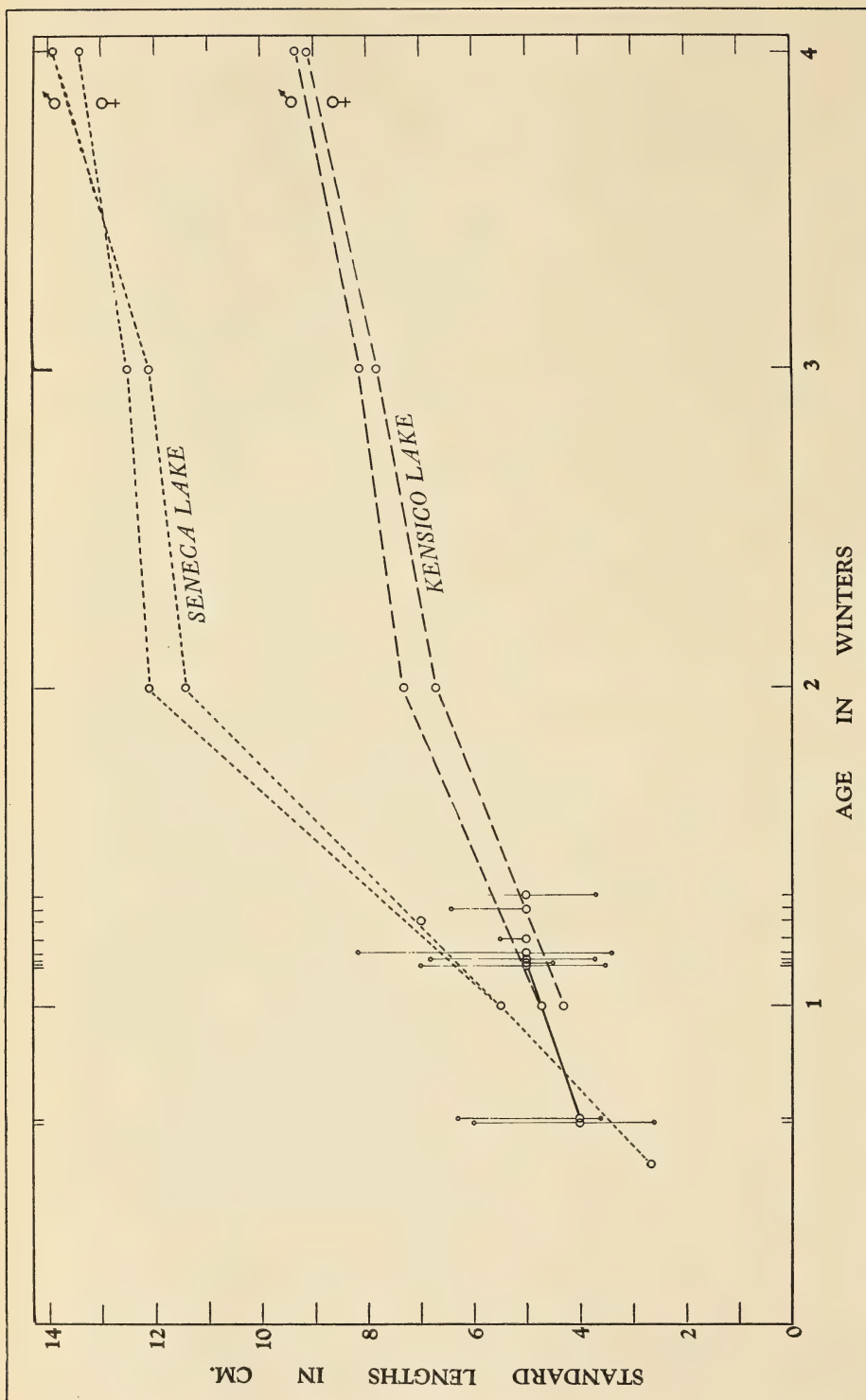
Text-figure 6.

Growth of *Pomolobus pseudoharengus*. The clear circles through which verticle lines pass to smaller circles represent, respectively, modes and extremes of all immature fish measured. Those before the first winter were taken by seine at the upper end of Kensico Lake in August and showed no annuli. Those past the first winter were taken from the outlet screens from February to May and showed one annulus. The dashed line shows calculated lengths of larger fish for the first four winters taken from the screens during the same period. The dotted line is from table 1 of Odell (1934) from Seneca Lake. The latter fishes have a clearly faster growth rate than the Kensico Lake fish. Modes of all mature Kensico fish are 10+ cm. for females and 10— cm. for males, (not shown in this figure). The maximum was a female of 14.0 cm. and the minimum a male of 9.0 cm.

interval. This species is preyed upon to a large extent by *Cristivomer*, as indicated by Eaton (1928) and Odell (1934). The latter is present in Kensico in small numbers. Forster (1935) has considered the lake trout, as well as other species, as factors in the control of this herring in Kensico Reservoir, a not unimportant item in the maintenance of a satisfactory water supply of a great city. The probable value of such control measures can hardly be estimated at this time.

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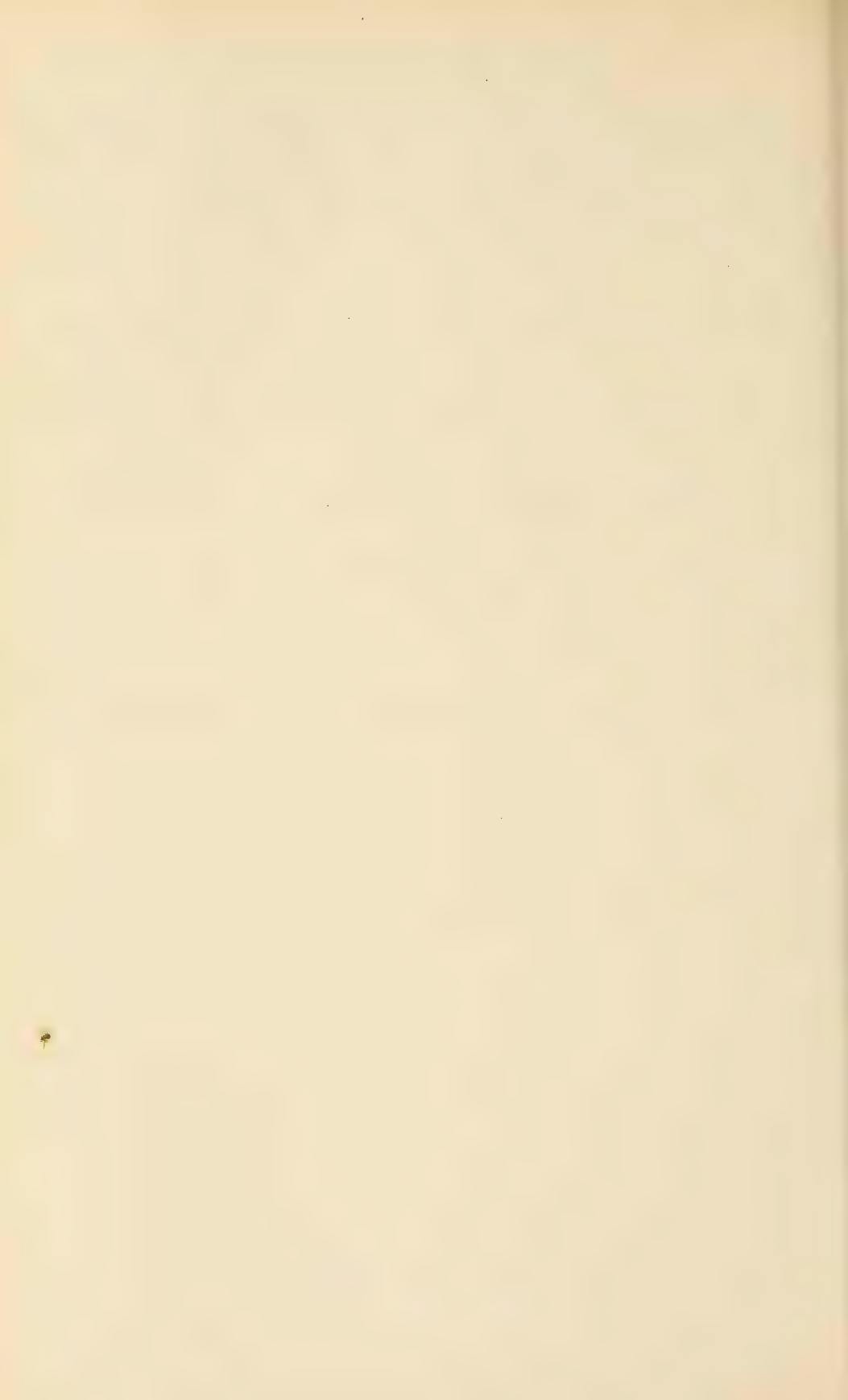
14.

Systematic Notes on Bermudian and West Indian Tunas of the Genera *Parathunnus* and *Neothunnus*[1].

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&
JOHN TEE-VAN

Department of Tropical Research,
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(Plates I-VII).

OUTLINE.

INTRODUCTION.

During 1934 and 1935 the game fishermen of Bermuda became interested in fishing for tuna and the result during those two years was the capture of at least 400 fish, ranging from 10 ounces to 60 pounds. Some fifty-three of these fish were brought to the Nonsuch laboratory during 1935 by various interested persons and the following notes have been made from investigations on these specimens. We are especially indebted to Mr. Childs Frick, Mr. and Mrs. E. J. Weir, Captain Christiansen, Major Davis, Mr. Leslie Howard, Mr. Robert Blackman, Mrs. Willett, Colonel Edwin Chance, Commander Landman and Mr. Beecham.

In addition to these Bermuda specimens we have been able to examine

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[1] Contribution from the Bermuda Biological Station for Research, Inc.
Contribution No. 501, Department of Tropical Research, New York Zoological Society.

critically twenty-eight examples of these fishes at various localities in the West Indies, while we were the guests of Dr. and Mrs. Henry D. Lloyd on board their yacht *Hardi Biaou.* All of the observations were made upon fresh specimens.

The name "tuna" in Bermuda is applied to three fish—the common tunny, *Thunnus thynnus* (Linnaeus), a rare fish at Bermuda; the yellow-finned tuna, *Neothunnus argentivittatus* (Cuvier and Valenciennes), known from Bermuda by two specimens recorded in this paper; and the black-finned tuna, *Parathunnus atlanticus* (Lesson). The present paper is concerned with the two latter species.

The taxonomy of the tuna and other mackerel-like fish is in great confusion. This is due both to the inadequacy of early descriptions, definitions and illustrations, to ignorance of the changes occurring during growth, as well as the difficulty of preserving large specimens for detailed laboratory examination. Many of the older descriptions are meager and lacking in necessary detail, and the result is that anyone searching the literature soon finds that he has at hand a mass of data that cannot be coordinated or correlated. For that reason the specimens in this paper have been described in detail, so that comparisons with fishes of other localities can be made more easily.

BLACK-FINNED TUNA
Parathunnus Kishinouye 1923.
Parathunnus atlanticus (Lesson) 1830.

(Plates I & II).

SYNONYMY.

Thynnus atlanticus Lesson, 1830, In Duperrey, L. I., Voyage autour du monde— sur la corvette . . . "La Coquille," pendant . . . 1822-25. Paris, 1830, II, p.165. (Trinidad Island, South Atlantic).

Thynnus balteatus Cuvier and Valenciennes, 1831, Hist. Nat. Poiss., VIII, p. 98 (136). (Trinidad Island, South Atlantic).

Parathunnus obesus (not of Lowe), Beebe and Tee-Van, *Zoologica*, X, 1928, p. 100 (Haiti).

Parathunnus rosengarteni Fowler, 1934, *Proc. Acad. Nat. Sci. Phila.*, LXXXVI, p. 354, 356, figs. 3, 4, 5, (Florida).

Parathunnus ambiguus Mowbray, 1935, Description of the Bermuda Large-eyed Tuna Parathunnus ambiguus, n. sp., by Louis L. Mowbray, Curator of Government Aquarium, Bermuda, May 1935. (Three page, unpaged, privately printed pamphlet). (Bermuda; type not designated).

Parathunnus atlanticus, Beebe and Hollister, 1935, *Zoologica*, XIX, 6, pp. 213-214 (Union Island, Grenadines, B. W. I.); Beebe, 1936, *Royal Gazette*, Hamilton, Bermuda, Jan. 20, 1936, p. 10 (Bermuda).

TAXONOMIC NOTES.

The Black-finned Tuna of the Western Atlantic has been named twice during the last three years, and investigation of the literature shows, as indicated in the preceding synonymy and the following notes, that at least two additional older names have been applied to this fish.

Cuvier and Valenciennes in 1831 gave a short description of a new species, *Thynnus balteatus*, stating "Cette espèce ne nous est connue que par un dessin fait par M. Lesson, vis-à-vis la Trinité, du Brésil, par les 20° de latitude australe, d'après un individu de vingt-huit pouces." The descrip-

tion is of a tuna with complete scalation and with a pectoral fin intermediate in length between the short pectoral of *Thunnus thynnus* and the exceptionally long pectoral fin of *Germo alalunga.*

However, Lesson a year earlier, in 1830, under the name of *Thynnus atlanticus,* had already described this same fish, evidently from the identical drawing, as he states in his description "Cette bonite a 28 pouces ...." "Nous primes cette bonite, non loin des Martin-Was et de l'île de la Trinite ...." Lesson's description is considerably longer and better than that given by Cuvier and Valenciennes. Evidently the latter authors saw only Lesson's drawing of the fish, which, apparently, was never published, and were not aware of his previous description.

The subsequent history of these two names is that they have usually been synonymized under the long-finned albacore, *Germo alalunga.* The latter name, as reference to Jordan and Evermann's "Fishes of North and Middle America," will show (I, p. 871), has been a catch-all for at least five authentic but poorly known species.

The identification of *atlanticus* and its synonym *balteatus* with *Germo alalunga* is quite wrong and the former species should be placed in the genus *Parathunnus.* As far as the pectoral is concerned, *Germo alalunga* possesses an exceptionally long fin, measuring some 2.3 to 3 times in the length of the fish—the tip of the fin usually extending beyond the posterior tip of the soft dorsal. *Atlanticus,* from the original description and from the description of the nominal *balteatus,* has the same measurement, 4.6 and 4 respectively, in the *total* length. These two proportions must be reduced somewhat as they are in the total length instead of the standard. However, even after being reduced, the figures show a fin considerably shorter in *atlanticus* than in *alalunga,* a condition that is specifically mentioned in the description of *balteatus.* In the original description of *atlanticus* and in our entire recent series the pectoral fin measures from 1 to 1.17 times in the length of the head.

These figures for fins and other characters given in the descriptions of *atlanticus* and *balteatus* agree with the accounts of *Parathunnus rosengarteni* and *Parathunnus ambiguus* and with recent Bermuda and West Indian specimens of *Parathunnus* examined by the present authors. In order to correlate the various accounts the following table is included, listing the proportions and counts of the various nominal forms and comparing them with our series of Bermuda and West Indian specimens and our previously reported Haitian specimen.

In reviewing the proportions and counts given under the various headings it will be noticed that the number of soft dorsal fin rays recorded for *atlanticus* in Lesson's original description is 8, this author making no distinction between rays and spines. This count is in disagreement with the descriptions of Fowler's *rosengarteni* (IV, 13), Mowbray's *ambiguus* (I, 12 to 13) and our Bermuda material, the latter being topotypical with Mowbray's *ambiguus.*[2] This discrepancy can be assigned either to the fact that Lesson, and Cuvier and Valenciennes described the species from an imperfect drawing or to the difficulty of counting the rays, a task that is especially troublesome in these fishes, as the fins are encased in rather thick skin and the rays and spines can be accurately counted only by removing the skin with a scalpel.[3]

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[2] The difference in fin count has already been ignored by previous authors when *atlanticus* was placed in the synonomy of *Germo alalunga.* The latter species has a fin count comparable to that of the later recorded specimens of *atlanticus.*

[3] In this respect it is of interest to note that until very recently the soft dorsal and anal fins of these fishes have been consistently described as possessing but a single anterior spine. Fowler (1928, Fishes of Oceania, pp. 132, 133 ; 1934, *Proc. Acad. Nat. Sci. Phila.*, LXXXVI, p. 354) has found a multiple number of spines in the anterior portion of the soft fins in a number of species, a condition that apparently holds true for most of the scombroids.

TABLE I.

Parathunnus atlanticus (Lesson). Proportions and counts of original descriptions and of a series of Bermuda and West Indian recent specimens.

	atlanticus, original description of Lesson, 1830	balteatus, original description of Cuvier and Valenciennes, 1831	rosengarteni, original description of Fowler, 1934	ambiguus, original description of Mowbray, 1935	atlanticus, series of 52 Bermuda specimens, Beebe and Tee-Van, 1935	atlanticus, series of 22 specimens, Tobago, B.W.I., Beebe and Tee-Van, 1936	atlanticus, 2 specimens from St. Lucia, B.W.I., Beebe and Tee-Van, 1936	atlanticus, 1 specimen from Grenada, B.W.I., Beebe and Tee-Van, 1936	atlanticus, 1 specimen from Haiti (recorded as obesus), Beebe and Tee-Van, 1928
Length in millimeters	710	710	713[1]	?("....1½ lbs. to 60 lbs.")	263 to 583	383 to 570	560	374	629
Length in inches	28	28	28	?("....1½ lbs. to 60 lbs.")	10.5 to 23	15 to 22.5	22	14¾	24
Depth in length	3.5*	...	3.66	3.4 to 3.6	3.12 to 3.76	3.7 to 4.05	3.4	3.5	3.6
Head in length	4*	...	3.5	3.3 to 3.5	3.1 to 3.4	3.25 to 3.6	3.15	3.4	3.3
Eye in head	4.67	...	4.87	5.3	4.35 to 6	5.2 to 5.5	5.2	5.2	5.2
Snout in head	...	...	3.2	3	3 to 3.5	2.9 to 3.3	3.2	3.3	3.3
Maxillary in head	...	...	2.5	2.4	2.45 to 2.5	2.4 to 2.5	2.5	2.5	...
Interorbital space in head	...	...	2.6	3	3 to 3.1	3.06 to 3.2	3	4	...
Dorsal Fin ⎰ Spinous	14	14	13	14	13 to 14	13 to 14	14	14	14
Dorsal Fin ⎨ Second	8	...	IV, 13[2]	I, 12 to 13	III or IV, 10 to 12[2]	III, 11[2]	IV, 11[2]	III, 12[2]	II, 12[2]
Dorsal Fin ⎱ Finlets	9	9	8	9	7 to 8	8 to 9	9	8	8
Anal Fin ⎰ Fin	8	...	IV, 11[2]	II, 12	II to III, 10 to 12[2]	III, 11[2]	III, 10[2]	III, 11[2]	II, 11[2]
Anal Fin ⎱ Finlets	8	...	7	8	7 to 8	7 to 8	8	7	8
Pectoral fin length in length	4.65*	4*	3.75	3.3 in 24″ fish, longer in smaller fish.	3.3 to 3.7	3 to 3.7	3.85	3.4	3.8
Pectoral fin length in head	1.17	...	...	...	1 to 1.1(1.37 in 263 mm. fish)	.9 to 1.08	1.24	1	...
Pectoral fin ray count	35	...	I, 30	...	I, 32-33	I, 31-32	I, 33	I, 30	...
Gill-rakers, upper limb	...	...	...	6	5 to 6	5 to 6	5	5	...
Gill-rakers, lower limb	...	...	...	17	15 to 18	15 to 16	15-16	16	17
Middle eye to snout in head	...	...	...	...	2.4 to 2.5	2.4 to 2.44	2.37	2.47	...
Snout to pelvic fin origin in length	...	...	...	...	2.75 to 2.9	2.8 to 2.9	2.8	2.95	...
Snout to 1st dorsal fin in length	...	...	...	...	2.95 to 3.2	3 to 3.1	3	3	...
Snout to 2nd dorsal fin in length	...	...	...	...	1.67 to 1.76	1.66 to 1.76	1.7	1.7	...
Snout to anus in length	...	...	...	...	1.45 to 1.5	1.46 to 1.53	1.5	1.5	...
Height 1st dorsal spine in head	2.3	...	2	...	2.2 to 2.45	2.15 to 2.5	2.35	2.5	...
Height 2nd dorsal fin lobe in head	2.3	...	2.25	...	2.7 to 3.1	3.1 to 3.6	2.9	3.6	...
Height anal fin lobe in head	2.3	...	2.5	...	2.85 to 3.4	3.2 to 4.2	3	4.2	...

* Proportions marked with an asterisk are taken in the total length of the fish, consequently these proportions must be reduced somewhat to conform with the other figures.

[1] Described from a mounted specimen.

[2] The last ray of the soft dorsal and anal fins is a finlet which is firmly connected with the fin, and is here counted as part of the soft dorsal and anal fins. The finlets, therefore, in the next line, are only those that are free and unattached.

As a further indication of the identity of these fishes the following excerpts of color descriptions are cited: In every description of the various forms assigned to *atlanticus* there is mention of a lateral golden, orange or coppery band. Thus Lesson states, "Une large band de cuivre rouge doré vient de l'oeil, suit un instant la courbe de la ligne laterale, et va se perdre sur les côtes du corps au point ou il s'amincet." Cuvier and Valenciennes write of *balteatus*, ". . . depuis le maxillaire supérieur jusqu'à la queue, une bande de coleur de cuivre doré." Fowler's description of *rosengarteni* contains the following, ". . . From behind the eye rather dark golden band crosses corselet and continues along below lateral line to caudal peduncle . . ."; while Mowbray in the description of *ambiguus* states: "Colour, blue black above, a bright blue stripe, with one of yellow below it, separates the upper colour from the lower, . . ."

From the foregoing paragraphs it becomes evident that in the western Atlantic there exists a species of tuna with complete scalation, possessing a pectoral fin intermediate in length between that of *Thunnus thynnus* and *Germo alalunga*, distinctive gill-raker count, and a conspicuous type of coloration with a lateral golden or coppery band, and that the specific name *atlanticus* can be removed from the synonomy of *Germo alalunga* and be established as the proper name for this fish.[4]

Parathunnus obesus Lowe, described from Madeira in 1839, is very close to the present species. From the literature, especially Frade's redescriptions (1929, 1931), one of the few definite characters separating the two species is the shape of the air-bladder, which in *atlanticus* is simple, quite short and broader than long—totally different from the relatively complex air-bladder shown by Frade for *obesus* (1931, p. 121). The disparity in size of Frade's fish and the western Atlantic series makes it difficult to make adequate comparisons in other characters.

The specimen recorded by Beebe and Tee-Van from Port-au-Prince Bay, Haiti (1928, p. 100) as *Parathunnus obesus* has been reexamined; it is definitely *Parathunnus atlanticus*.

DESCRIPTION OF BERMUDA AND WEST INDIAN SPECIMENS.

The following description is based on previously published accounts plus notes made on the specimens that we have examined. In addition, the Table on Page 180 should be consulted for measurements and proportions not otherwise mentioned.

Parathunnus atlanticus.

Body thickset, spindle-shaped. Smaller individuals slightly more compressed laterally than the larger. Depth 3.12 to 4.05 in the length, the greatest depth of body about half way from base to tip of pectoral fin. Caudal peduncle depressed, with a triangular, rather short dermal keel on each side, the length of the keel being about one and one-half to two times the diameter of the eye. On the base of the caudal peduncle above and below the large keel is a very short, oblique dermal keel. A small keel on the body above the upper edge of the pectoral fin which allows the upper edge of the fin to lie flat with the contour of the body.

Body completely scaled, the scales small, compact, absent on head, smallest below, especially anteriorly—those between the pectoral and ventral fins minute. Scale from midside at vertical of the origin of the second dorsal

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[4] If, very improbably, the Trinidad Island, South Atlantic fish *atlanticus* should prove to be different from the West Indian, Florida and Bermuda Black-finned Tuna, Fowler's *rosengarteni* will be the proper term for the northern form.

fin in a 443 mm. fish measuring 2.75 mm. high and 2.6 mm. long. Corselet small, inconspicuous, largely over the base of the pectoral.

Lateral line complete, slightly wavy, not very high anteriorly, becoming median in position only on the posterior caudal peduncle.

Head conical, 3.15 to 3.6 in standard length, the lower profile slightly more convex than the upper. Snout not especially sharp, 2.9 to 3.25 in the head length. Eye large, obliquely set in head, 4.35 to 6 in head length (5.3 to 6 in fish over 380 mm.) ; adipose eyelid very small; interorbital space convex, 2.6 to 3.6.

Posterior nostril an elongate vertical slit, its length slightly less than one-half the eye diameter. Anterior nostril very small, situated a considerable distance anterior to the posterior nostril and at the level of the upper edge of the latter.

Mouth oblique, the mouth opening convex when viewed from the side, the convexity being upward. Maxillary 2.4 to 2.5 in the head, its posterior margin extending from anterior margin of eye to anterior margin of pupil, the width of the posterior expansion being about 2 in the diameter of the eye.

Teeth moderate in jaws, uniserial, simple, conic, 33 to 40 above on each side (27, Fowler), 32 to 41 on each side below (32, Fowler). Vomer, palatines and a patch on the tongue with finely granular teeth.

Gill-rakers slender but strong, 4 to 6 plus 15 to 18 on the first gill-arch. In 58 specimens in which the gill-rakers were counted, 13, or 22 percent., had asymmetrical counts on the arches of the right and left sides. The seven combinations of the gill-raker counts in these thirteen specimens are as follows:

Gill-Rakers	Number of specimens
4+16 — 5+16	1
5+15 — 5+16	3
5+16 — 6+17	3
5+17 — 6+16	2
5+18 — 6+18	1
6+15 — 6+16	2
6+16 — 6+17	1

The remaining forty-five fish with symmetrical gill-raker counts distribute themselves as in the following table:

Rakers on upper limb of first gill-arch	Rakers on lower limb of first gill-arch		
	15	16	17
5	5	13	1
6	..	15	11

Dorsal fin XIII to XIV—III or IV, 10 to 13 (last ray a connected finlet)—VII to IX. Second dorsal spine highest, the first almost as high as the second, the spines after the second becoming progressively shorter, first abruptly and then gradually. Soft dorsal low. Anal fin II to III, 10 to 12 (last ray a connected finlet)—VII to VIII. Anal lobe similar to dorsal in shape and size.

COLORATION: This species in life is exceedingly brilliant. A 555 mm.

specimen whose colors were recorded before the fish was removed from water was described as follows: Dorsal surface and inner side of pectoral fins jet black, the former bordered laterally with bright blue. A lateral band from snout to tail of brilliantly iridescent shining gold, very wide and including the outer side of the pectoral fin. Lower sides shining silver, with a large oval patch on the sides between the pectoral and pelvic fins silvery iridescent. Sides and ventral parts with eleven vertical bars and an equal number of bands of spots alternating with the bars. Second dorsal lobe with a tinge of yellow, but all other vertical fins black with a narrow white border, especially marked on the finlets.

Mowbray's description of his specimens is as follows: "Colour, blue black above, a bright blue stripe, with one of yellow below it, separates the upper colour from the lower, which is a silvery gray; region of the ventrals and the belly, milky white: the spinous dorsal is dusky, the membrane lighter than the spines.

"The soft dorsal and anal are dusky with a silvery lustre, the finlets are dusky, with a trace of yellow: this is more pronounced in some specimens: the pectorals are black, the base outwardly is washed with silver.

"The ventrals are milky white outwardly when closed, and dusky inwardly with a metallic lustre when opened: the caudal is dusky, the sides of the belly show white spots which appear as reticulations: this I believe to be seasonal, as I noticed them only in the winter months; I do not know if they disappear in G. alalunga or not."

There is considerable variation in color and in some specimens the lower side of the pectoral fin is silvery, the fin not being included in the golden lateral band. At death the golden band fades rapidly and usually only traces of it remain.

The finlets and the vertical fins are occasionally greenish, as stated by Mowbray, or even yellowish, but the fins are never as brilliantly colored as in *Neothunnus argentivittatus*. These two species need not be confused on this score, as the gill-rakers give an absolute differentiation in questionable specimens.

The colors of the smallest known specimen of *Parathunnus atlanticus* (263 mm.) were noted as follows: Bluish black above shading to grayish silvery on the sides and whitish below. Middle of sides somewhat lead-colored and with a series of five to six vertical lighter colored bands on the lower sides, extending upward as far as the median line of the body. These bands, posteriorly, are changed into series of horizontal, elongate spots forming broken vertical bands (see Pl. II, Fig. 4). Spinous dorsal, soft dorsal and dorsal finlets dusky, the latter with a pale upper edge. Pectoral blue-black above, grayish silvery below, darker toward the tip. Caudal fin dusky. Lower surface of pelvic fin white, upper surface dusky with a yellowish tinge, the rays brownish.

Mowbray states (1935) that "The white spots or reticulations supposed to occur only in young specimens of Germo are not present in the smaller specimens of this species." Our smallest fish, however, as described above, did have such spots and we have seen the pattern in other fish of this species in the West Indies. (See Pl. II, Fig. 4 of a Bermuda fish, and Pl. I, Fig. 2 of a fish from St. Lucia, British West Indies).

In other tunas this pattern is a juvenile one, and it has been previously reported from *Thunnus thynnus*[5], *Thunnus orientalis*[6], *Neothunnus argentivittatus*[7], *Neothunnus macropterus*[8] and *Parathunnus mebachi*[9].

[5] Frade, 1929, *Bull. Soc. Portugaise des Sciences Nat.*, X, No. 20, 236.
[6] Kishinouye, 1923, *Journ. Coll. of Agriculture, Imp. Univ. of Toyko*, VIII, No. 3, 438-439.
[7] Cuvier and Valenciennes, 1831, Hist. Nat. Poiss., VIII, 98.
[8] Kishinouye, 1923, *Journ. Coll. of Agriculture, Imp. Univ. of Tokyo*, VIII, No. 3, 447.
[9] Kishinouye, 1923, *Journ. Coll. of Agriculture, Imp. Univ. of Tokyo*, VIII, No. 3, 444.

SIZE AND WEIGHT: This species, according to Mowbray, grows to a weight of 60 pounds. The sizes and weights of a few individuals measured by us are as follows:—

| Length | | Weight |
Millimeters	Inches	Pounds
263	10.3	13 ounces
374	14.8	2.25
443	17.5	4.5
475	18.7	6.25
480	18.9	6.5
495	19.5	7.
530	21	6.75
560	22	11
583	23	12.5
660	26	15.5

RANGE.

Known from the coast of Florida, Bermuda, Haiti, Martinique, the following islands in the British West Indies: St. Lucia, Union, Grenada and, Tobago, and from Trinidad Island, Brazil.

YELLOW-FINNED TUNA.

Neothunnus Kishinouye 1923.
Neothunnus argentivittatus (Cuvier and Valenciennes) 1831.

(Plates III-VII).

SYNONOMY.

? *Scomber albacares*, Bonnaterre, 1788, Tableau Encyc. Meth., Ichth., 140 (Madeira; after a drawing by Sloane, 1707).
? *Scomber sloanei*, Cuvier and Valenciennes, 1831, Hist. Nat. Poiss., VIII, 107 (Madeira; after a drawing by Sloane, 1707).
Thynnus argentivittatus, Cuvier and Valenciennes, 1831, *Hist. Nat. Poiss.*, VIII, 97 (Atlantic and Pacific Oceans).
Thynnus albacora, Lowe, 1839, *Proc. Zool. Soc. London*, VII, 77 (Madeira).
Thunnus allisoni, Mowbray, 1920, *Copeia*, 78, Feb. 11, 1920, 9-10. fig. (Florida).
Neothunnus albacora, Frade, *Rapp. Cons. Explor. Mer.*, 1931, 70, 123.
Neothunnus argentivittatus, Beebe, *Royal Gazette*, Hamilton, Bermuda, Jan. 20, 1936, 10 (Bermuda).

TAXONOMIC NOTES.

In 1707 Hans Sloane in "A Voyage to the Islands Madera, Barbados, Nieves, S. Christophers and Jamaica, with the Natural History .... of those Islands," Vol. I, p. 11, described a tuna from Madeira. His description of the fish is as follows:

"The Sea hereabout is very well provided with *Albacores*, or *Thynni*, whose Description follows.

"The Fish was Five Foot long from the end of the Chaps to that of the Tail, the Body was of the make and shape of a Mackarel, being roundish

or torose, covered all over with small Scales, White in some places, and Darker coulour'd in others, there was a Line run along each side. The coverings of the Gills of each side were made of two large and broad Bones covered with a shining Skin, the Jaws were about Six Inches long, having a single row of short, strong, sharp Teeth in them, and were pointed. The Eyes were large, and the Gills very numerous, behind which were a small pair of Fins. *Post anum* was a Foot long Fin, about Three Inches broad at bottom, and Tapering to the end. It had another on its Back answering that on the Belly, and from these were small *Pinnulae* at every Two Inches distance to the Forked Tail, which was like a New Moon falcated, before which on the Line of the two sides was a membranous thick horny Substance, made up of the Fishes Skin, stood out about three-quarters of an Inch where it was highest, something like a Fin. It was about Three Foot Circumference a little beyond the head, where it was thickest. The Eye was about an Inch and a half Diameter. The Figure of this Fish is here added, Tab. 1, Fig. 1 taken from a dried Fish, where everything was perfect save the first Fin on the Back, which I suppose was accidentally rub'd off.

"It is frequently taken by Sailers with Fisgigs or White Cloath, made like Flying-fish, and put to a Hook and Line for a Bait; the Flesh is coloured and Tasts as the *Tunny* of the Mediterranean, from whence I am apt to believe it the same Fish. It is to be found not only about Spain, and in the way to the *West-Indies;* but in the South-Seas about *Guayaquil,* and between Japan and New-Spain every where."

From this account and figure (See Pl. VII, Fig. 13), Bonnaterre, in 1788, described *Scomber albacares*, and forty-three years later (1831) from the same data Cuvier and Valenciennes described *Scomber sloanei*.

Bonnaterre's description of *albacares* is as follows: "*L'Albacore* 9. *S. Albacares S. pinnulis plurimus*: *aristes duabus supra opercula, membrana lucida tectis.*

"Plusieurs fausses nageoires: deux arêtes couvertes d'une peau luisante au dessus des opercules.

"Le corps est rond & entièrement couvert de petites écailles: les mâchoires, dont la longeur est d'environ six pouces, sont armées d'une seule rangée de dents courtes & très-aiguës. La nageoires du dos correspond à celles du ventre; elle est accompagnee de plusieurs fausses nageoires, éloignées les unes des autres, d'environ deux pouces; la nageoire de l'anus a un pied de long, fui trois pouces de large: elle se termine en pointe; celle de la queue est echancrée en croissant; les parties latérales de la queue forment, de part & d'autre, une saillie en carène, qui a trois quarts de pouce d'elevation. Quelqus parties du corps sont blanches; les autres sont d'une couleur foncée. Ce poisson a trois pieds de circonférence dans sa plus grande époisseur, & cinq pieds de longueur. *Sloane Hist. tho. Jamaic. vol. 2, p. 11. La Jamaique.*"

The following is Cuvier and Valenciennes' description of *Scomber sloanei*:

L'Auxide de Sloane.
(*Scomber Sloanei*, nob.)

"L'*albacore* de Sloane, si l'on peut s'en rapporter à une figure grossière, comme toutes celles qu'a données cet auteur, semble devoir appartenir à ces thons à dorsal écartées.

"Son museau est court; sa bouche, peu fendue, n'a que de petites dents. Sa première dorsale paraît avoir peu de rayons, et être séparée par un grand intervalle de la seconde. Ses pectorales sont courtes. Il a huit fausses nageoires en dessus, et sept en dessous de la queue; mais ce qui

paraît devoir lui former un caractères spécifique, c'est que sa seconde dorsale et son anale sont plus hautes et plus pointues à proportion, que dans aucune autre espèce; elles ont en hauteur plus du cinquième de la longueur totale. Nous n'avons rien vu qui ressemble à cette figure."

The identity of Sloane's fish and consequently of the names *Scomber albacares* and *Scomber sloanei,* has always been questionable, and while Sloane's fish was, most probably, the long-finned, yellow-finned tuna here discussed, we cannot be certain of this because of discrepancies between modern specimens and Sloane's description, especially those relating to the length of the pectoral fins.

Sloane does not state the color of the fins of his fish. If he had, there would be considerable less difficulty in assigning a position to his tuna. The condition of the dorsal fin as shown in his figure, with a long space between the spinous and soft dorsal, which caused Cuvier and Valenciennes to assign a common name of "L'Auxide de Sloane" to this fish, may be explained by the fact that Sloane specifically states that the fin was damaged; this major discrepancy can thus be removed from the description of the fish. However, the one character that stands out in marked contrast to our knowledge of recent specimens of yellow-finned tuna is the length as shown in Sloane's figure of the pectoral fin. These fins are very much shorter than those of recent specimens, and Sloane definitely states of these fins ". . . and the Gills very numerous, behind which were a small pair of Fins."

We are thus left with the uncertainty as to the status of Sloane's specimens and the associated names, and while we might assume that the illustration was carelessly drawn with fins of wrong length, yet Sloane's definite statement in the text as to the size of the fins prevents our using either of the earlier names as the correct one for the yellow-finned tuna of the Atlantic.

It is of interest that modern authors such as Jordan and Evermann 1896, Jordan and Evermann 1926, Jordan, Evermann and Clark 1930, and Fowler 1928, have repeatedly given the type locality of *Scomber albacares* Bonnaterre as Jamaica. This is an error and the fish, according to Sloane's volume, was originally taken at Madeira.

The earliest valid description of the Atlantic yellow-finned tuna is that of Cuvier and Valenciennes, who in 1831, described *Thynnus argentivittatus* from a drawing of an Atlantic specimen taken by Quoy and Gaimard. The fish they described was a completely scaled tuna with pectoral fin intermediate in length between that of the common tuna and the long-finned albacore, *Germo alalunga,* and with a conspicuous coloration consisting of bright yellow fins and a combination of alternate white vertical bands and groups of spots on a slightly darker belly.

Lowe, in a brief description published in 1839, described *Thynnus albacora* from Madeira. This form was forgotten, as far as the literature is concerned, until the last few years, during which a number of observers have described it from various localities in the eastern Atlantic, the principal accounts being by Frade. Lowe recognized that the fish mentioned by Sloane was similar to his as he synonymized Sloane's account, and Cuvier and Valenciennes' *Scomber Sloanei* under *Thynnus Albacora.*

Mowbray in 1920 described *Thunnus allisoni* from Florida. This is the typical long-finned and yellow-colored large adult form of the species.

Study of the original descriptions of *argentivittatus* Cuvier and Valenciennes, *albacora* Lowe, the redescriptions of *albacora* by Frade, the original description of *allisoni* Mowbray, a single specimen taken by us in Bermuda, another Bermuda specimen taken in Bermuda by Mrs. W. B. Holler, and five fish taken by us in the West Indies, lead us to believe that all of these

relate to one species for which the name *argentivittatus,* Cuvier and Valenciennes, 1831, has priority.

Cuvier and Valenciennes' description of *argentivittatus* and the smaller Bermuda and West Indian specimens agree in possessing low dorsal and anal fin lobes, in contradistinction to the other original descriptions and our larger West Indian specimens. This condition is discussed on later pages.

The detailed measurements and proportions of the various original descriptions plus those of recent specimens, demonstrating the similarities, are shown in the table on Page 188.

Comparison of Specimens with High and with Low Soft Dorsal and Anal Fin Lobes.

The Atlantic species of *Neothunnus, N. argentivittatus,* (including *N. albacora*) and its Pacific congener *Neothunnus macropterus,* agree in possessing forms with short soft dorsal and anal fin lobes and others in which these fins are considerably produced, a fact that has caused discussion as to the specific validity of these types.

The preponderance of opinion, so far, both as to the Atlantic and Pacific species, has been that the high and the low-finned forms are the same, although Fowler (Proc. Acad. Nat. Sci. Phila., LXXXV, 1933, p. 163) evidently disagrees with this and has erected the genus *Semathunnus* for those with high soft dorsal and anal fin lobes, leaving the low-finned fish in *Neothunnus.*

Our recent observations of *argentivittatus* at Bermuda and in the West Indies, and its Pacific relative *macropterus* in the Gulf of California, coupled with examination of the literature has convinced us that the forms are the same species, possessing short soft dorsal and anal fin lobes while small, as Frade (1929) has already stated, the lobes becoming produced with growth. In the larger specimens there is a tendency for the fins to vary in length, some specimens having relatively long fins while in others they are relatively shorter. The fins of the same fish are not always equal in length (See Table II, last column) and Herre (1936) states of hundreds of Pacific *N. macropterus* that he examined: "Sometimes the anal, more rarely the dorsal, lobe would be elongated and the other remain comparatively short."

As far as the literature is concerned the following quotations are pertinent. Cunningham (Proc. Zool. Soc. London, 1910, p. 106), writing of *albacora* (which we here synonymize with *argentivittatus*) and comparing it with *Parathunnus obesus* and *Germo alalunga* states: "In one form, namely the common albacore of the inhabitants of St. Helena—there are considerable changes in the course of growth: but these changes do not lead to any approximation to the other forms but rather to a greater development of the special features: in a small specimen somewhat less than 3 feet in length the second dorsal and the first ventral [anal] fins were scarcely higher than in the other two forms, while in the other specimens the great vertical elongation of the fins is very characteristic." (See Pl. III, Fig. 5 of a Cunningham specimen).

Frade in speaking of his Atlantic specimens says: "Il est interessant de signaler que, comme pour *N. macropterus* du Pacifique, il existe pour la même taille deux types de *N. albacora;* l'un à 2e dorsale et anales longues, correspondant à *N. macropterus* forma *itosibi* et l'autre à 2e dorsale et anales courtes, correspondant à *N. macropterus* forma *macropterus.*"

Kishinouye, in his excellent study of Japanese *Neothunnus macropterus,* says: ". . . The second dorsal and anal are much elongated, especially in the variety named itoshibi or gesunaga, the tips of these fins are whitish and reach to the base of the caudal. So far as I have examined there is no

TABLE II.

Neothunnus argentivittatus (Cuvier and Valenciennes). Proportions and counts of original descriptions and of a series of recent Bermuda and West Indian specimens.

	argentivittatus, original description of Cuvier and Valenciennes, 1831	albacora, original description of Lowe, 1839	albacora, redescriptions of Frade, 1931	allisoni, original description of Mowbray, 1920	argentivittatus, 1 specimen from Bermuda, Beebe and Tee-Van, 1935	argentivittatus, 1 specimen from St. Lucia, B.W.I., Beebe and Tee-Van, 1936	argentivittatus, 1 specimen from St. Lucia, B.W.I., Beebe and Tee-Van, 1936	argentivittatus, 1 specimen from St. Lucia, B.W.I., Beebe and Tee-Van, 1936
Length in millimeters	686	?	991 to 1740	1752	555	645	690	1450
Length in inches	27	?	39 to 68	69	22	25	27	57
Depth in length	Proportions stated as being similar to common tunny	....	3.85 to 4.85	3.5	3.6	3.9	3.75	3.55
Head in length		....	3.5 to 4.2	3.87	3.34	3.4	3.5	3.9
Eye in head		....	6 to 10	7	5.7	6.2	6.4	8
Snout in head		....	(See below, middle eye to snout)	2.75	3.2	3	2.9	2.72
Maxillary in head		....		....	2.6	2.6	2.6	2.64
Interorbital space in head		....	2.25 to 3.25		2.7	2.87	2.9	2.5
Dorsal Fin — Spinous			14	14	14	14	14	14
Dorsal Fin — Soft	14 (no mention of height)	? (produced)	? (produced and not produced)	I, 11 (produced)	IV, 11 (not produced)	III, 11 (not produced)	III, 11 (not produced)	III, 10 (produced)
Dorsal Fin — Finlets	9	.....	8 to 10	9	9	8	9	9
Anal Fin — Fin	11 (no mention of height)	? (produced)	? (not produced and produced)	I, 11 (produced)	III, 11 (not produced)	IV, 10 (not produced)	III, 11 (not produced)	III, 10 (produced)
Anal Fin — Finlets	9		8 to 10	9	9	8	8	9
Pectoral fin in length	3.5*	4 to 5* (But tip reaches to middle of 2nd dorsal fin!)	3.45 to 4.65	"nearly equal to head"	3.45	3.5	3.4	4
Pectoral fin ray count	34	....	....	....	34	34	35	....
Gill-rakers, upper limb	....	....	....	9	10 to 11	9	9	10
Gill-rakers, lower limb	....	....	....	21	21	21-22	21	20
Middle eye to snout in head length	....	....	2.2 to 2.5	....	2.4	2.96	2.35	3.42
Snout to pelvic fin origin in length	....	....	3.1 to 3.6	....	....	3.1	3.1	3.55
Snout to first dorsal fin in length	....	....	3.1 to 4	....	3.1	....	3.1	....
Snout to second dorsal fin in length	....	....	1.7 to 2.1	....	....	1.75	1.8	1.88
Snout to anus in length	....	....	1.6 to 1.85	2	1.8	1.68	1.7	1.76
Height 1st dorsal spine in head	....	....	....	....	....	2.35	2.35	2.05
Height 2nd dorsal fin lobe in head	....	....	....	....	....	2.35	2.15	1
Height anal fin lobe in head	....	....	....	....	....	....	2	.55
Possesses silver bars and spots on lower sides	Yes	....	Yes in young	....	Yes	Yes	Yes	No

* Proportions marked with an asterisk are taken in the total length of the fish, consequently these proportions must be reduced somewhat to conform with the other figures.

marked difference in anatomical structure between the long-finned variety and the ordinary form, except in the length of the second dorsal and anal fins."

Combining the facts in these quotations with our own observations we come to the following conclusions: There is evident agreement that the dorsal and anal fins are low in the smaller individuals and grow longer in the larger: There is less agreement as to what happens in the fins of the fishes of larger size. Both Frade and Kishinouye state that there are two forms, a short-finned and a long-finned, and the former queries (1929, p. 238) as to the possibilities of these being different sexes. It is our belief that intermediate forms will be found completely connecting the two groups.

Two references relating to the closely related Pacific *Neothunnus macropterus* are in accord with this statement. Thus Herre (1936, pp. 106, 107) says: "I have examined many hundreds of this fine fish, alive, just taken from the water, and after preservation in ice, in the Philippines, and have also examined vast numbers of them in Japan. I agree with the late Dr. Kishinouye that there is no difference between those with the anterior dorsal and anal lobes of ordinary height and those in which the lobes, particularly the anal, extend to the base of the caudal or beyond. In a lot of several hundred caught in a fish corral at one time, there would be every graduation in the length of the dorsal and anal lobes. Sometimes, the anal, more rarely the dorsal, lobe would be elongated and the other remain comparatively short. My observations have been made upon specimens ranging in weight from 30 to 40 pounds up to those weighing nearly 400 pounds, their lengths varying from two-thirds of a meter to nearly three meters."

Walford (1936) writing of the Pacific yellow-finned tuna examined by him in canneries says: ". . . Among several hundred specimens that I examined there, the dorsal and anal fins were of all lengths, intergrading to such an extent that it is impossible to separate them into two groups. In general, the largest, consequently the oldest fish had the longest fins. Unless there are some other characters to separate the two—and no one has as yet been able to find any—it thus looks as if the Allison tunas of the Pacific coast are merely old specimens of the yellowfin."

The following table correlates the height of the dorsal and anal fin lobes in a series of Atlantic yellow-finned tuna of progressively larger size.

Locality	Length, mm.	Percent of standard length	
		2nd dorsal lobe	Anal lobe
Bermuda, Dept. Trop. Res. No. 25,206..	577	10.8%	10.1%
St. Lucia, B.W.I., Dept. Trop. Res. No. 24,682.	645	12.5%	broken
St. Lucia, B.W.I., Dept. Trop. Res. No. 24,683.	690	13.3%	14.3%
St. Helena, Cunningham, 1910 (P.Z.S.) (Photograph).	930 app. Nearly three feet long	12.5%	?
Bermuda, (Holler specimen).	1,220	21%	22%
St. Lucia, B.W.I., Dept. Trop. Res. No. 24,690.	1,360	38.5%	48%
St. Lucia, B.W.I., Dept. Trop. Res. No. 24,689.	1,450	36%	48%
Portugal, Frade, 1929.	1,560	36%	39%
Canary Islands, Frade, 1931.	990 to 1,740	36%	34.5%
Canary Islands, Frade, 1931.	App. 1,600	35%	38%

It seems evident from the above tables and the preceding notes that the various nominal forms of the yellow-finned tuna belong to the same species, and that the forms typified by the large Allison's tuna represent but large-finned specimens of the smaller shorter-finned individuals. It is also evident that the genus *Semathunnus,* as far as Atlantic *argentivittatus* and Pacific *macropterus* are concerned, is untenable.

Description of Bermuda and West Indian Specimens.

The following description is of the first specimen taken at Bermuda: ♂, No. 25,206, Department of Tropical Research, New York Zoological Society; taken one mile south of Nonsuch Island, Bermuda, with rod and line by Mr. Beecham, July 27, 1935. Standard length 555 mm.; weight 8 pounds.

Field Characters: Robust, large, spindle-shaped, large-eyed fish with a fleshy keel on each side of the caudal peduncle and a series of finlets following the dorsal and anal fins; pectoral fins rather long, extending almost to the posterior end of the soft dorsal fin. Twenty-one gill-rakers on the lower limb of each gill arch. Dark blue above, white below; a series of alternate vertical narrow whitish bands and groups of spots on the lower sides. Dorsal fin and dorsal and anal finlets bright yellow.

Description: Body spindle-shaped, the depth 3.6 in the length, somewhat compressed, the greatest width of the body being 5.55 in the length; upper profile slightly more arched than the lower; caudal peduncle with a large, rather wide, dermal lateral keel and with two very small keels at the posterior end of the large keel—the latter is widest in its central portion tapering equally anteriorly and posteriorly. A groove along the sides into which fits the upper border of the pectoral fin.

Body covered with very small scales, smaller on the belly and larger immediately above the pectoral fin; corselet indistinct.

Lateral line indistinct anteriorly and slightly undulating, descending at the level of the posterior part of the spinous dorsal, posterior portion straight.

Head 3.34 in length; opercle gently rounded posteriorly; preopercle with its posterior limb not quite vertical and slightly concave.

Eye large, 5.73 in head and 1.8 in the snout, its vertical diameter slightly greater than the horizontal one. Adipose eyelids very slightly developed.

Anterior nostril minute, situated slightly nearer eye than tip of snout; posterior nostril a vertical slit, half an eye diameter in length and placed about one-third an eye diameter in front of eye.

Maxillary extending almost to anterior margin of pupil, its inferior margin rather abruptly downturned posteriorly. 31 to 34 teeth in each side of each jaw; the teeth small, conical and turned slightly inward. A granular patch of teeth on vomer and palatines.

Gill-rakers 10 or 11 plus 21 on first gill arch, the length of a median raker of the lower half of the arch being about 7/8 the diameter of the eye.

Dorsal fin XIV-IV, 11-IX, folding into a groove; first spine highest, the upper margin of the fin descending rather abruptly, the fifth spine only one-half as high as the first, the last spine a mere nubbin of 3 mm. Space between spinous and soft dorsal about equal to interspace between spines so that the two fins are practically continuous. Soft dorsal fin rather low, the height of the fin being 2.7 in the head and 2.6 in the pectoral length; fin followed by 8 free finlets.

Caudal fin with its posterior margin crescent-shaped, the expanse of the fin being slightly greater than the length of the head.

Anal fin originating under the next to the last ray of the soft dorsal, its lobe similar in shape to that of the dorsal; III, 11-IX. The first finlet of the nine is connected to the end of the anal fin.

Pectoral fin originating under origin of the spinous dorsal, the tip of the fin extending to the vertical of the 6th to 7th ray of the soft dorsal. Upper and lower margins of the pectoral fin almost parallel for the anterior half of the fin.

Pelvic fin originating under the anterior third of the pectoral fin base.

Measurements:
Total length: 577 mm.
Standard length: 555 mm.
Depth: 154 mm. (3.6).
Width of body: 100 mm.
Head: 166 mm. (3.34).
Eye: 29 mm. Greatest vertical diameter of eye: 32 mm.
Interorbital: 61 mm.
Snout: 52 mm.
Maxillary: 63 mm. Width of posterior expansion of maxillary: 13.5 mm.
Pectoral length: 161 mm.
Pelvic fin length: 60 mm.
Second dorsal fin lobe height: 62 mm.
Anal fin lobe height: 62 mm.
Height 1st dorsal spine: 63 mm.
Expanse of caudal fin: 185 mm.
Length of central caudal keel: 63 mm.
Greatest width across caudal keels: 49 mm.
Snout to middle of eye: 68 mm.
Snout to origin of 1st dorsal fin: 179 mm.
Snout to origin of pelvic fin: 188 mm.
Snout to origin of pectoral fin: 167 mm.
Snout to anus: 336 mm.

Counts:
Pectoral fin rays: 34.
Pelvic fin rays: I, 5.
Dorsal fin: XIV-IV, 11-IX.
Anal fin: III, 11-IX, first finlet connected to end of anal fin.
Gill-rakers: Right side 11 plus 21; left side 10 plus 21.
Teeth: Upper right 32; upper legt 33; lower right 31; lower left 34.

Coloration: Above dark metallic blue becoming silvery below, with purple and lilac iridescence in an indefinite band on each side of the white belly from the gills to the anal fin. Lower sides below the pectoral fin with eight more or less vertical whitish bars, alternating with similar vertical lines of small whitish spots, all on a dark grayish background. Pectoral fin silvery below, dark blue above; dorsal spines surrounded by narrow zone of yellow, which is less bright on the membrane of the fin; second dorsal orange-yellow, darker anteriorly, with a narrow black posterior edging and a small white tip to the fin; dorsal finlets bright yellow with dark margins; anal fin silvery at base, the remainder orange-yellow; anal finlets similar to dorsal but with considerable white posteriorly; pelvic fins dead white below; the rays when spread open are orange.

Variation: This species except for fin-lengths, which are discussed on preceding pages, does not differ much with age. The variations in propor-

tions are shown on the table recording the various specimens and original descriptions.

The white spots and bars on the lower sides of smaller fish are not visible on the larger individuals that we have seen.

Frade in his 1929 paper describes the coloration of his large fish as follows: "Coloration générale des spécimens adultes: toute la région dorsal au-dessus du bord supérieur de l'oeil et de la ligne latérale, et la queue, d'un bleu de Prusse opaque, plus clair vers la ligne latérale; regions operculaire, mandibulaire et ventrale d'un blanc métallique, ligèrement carminé, avec des tonalités verdâtres surtout vers la région anale. Ière dorsale avec les rayons cendrés jaunâtres et la membrane partageant de la même coleur mais plus foncée; 2ème dorsale et anale jaune foncé, s'atténuant vers l'extrémitié, l'anale avec des tons argentés sur la base. Pectorale verdâtre, la pointe noir bleuâtre; ventrale nacrée; caudal noir bleuâtre, jaunissant vers les extrémitiés. Pinnules jaune vif, liserées de noir."

A 1,450 mm. fish taken by us at Castries, St. Lucia, B.W.I., was recorded as follows: Dorsal surface bluish black changing into iridescent steel blue along the sides and silvery bluish white below; from anal fin to caudal the body below is silvery white. First dorsal with spines and most of the distal halves of the webs olive yellow. Second dorsal lobe yellow on distal third and yellowish to base of each edge. Anal lobe same as second dorsal. Caudal fin dark brown with yellow-white toward tips. Finlets bright chrome yellow with strong narrow black margins, especially prominent on the posterior edges.

In the smaller specimens the entire dorsal and anal fin lobes are brilliant yellow, and occasionally there is a golden band along the side of the fish from the snout through the eye above and over the pectoral fin. The smaller specimens also are characterized by the series of vertical alternate bars and groups of spots.

SIZE AND WEIGHT: The sizes and weights of a series of individuals of this species are as follows:

Length		Weight
Millimeters	Inches	Pounds
555	22	8
645	25.4	12
690	27	16
1220 (total)	48 (total)	45
1450	57	140
1750 (total)?	69 (total)?	143

RANGE.

Known from Scotland (?), Portugal, Angola, Canary Islands, Madeira, Bermuda, Florida, Martinique, St. Lucia, and St. Helena.

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EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. *Parathunnus atlanticus* (Lesson). Copy of the original illustration of the type of *Parathunnus rosengarteni* Fowler, the drawing made from a mounted specimen.

Fig. 2. *Parathunnus atlanticus* (Lesson). 560 mm. (23½-inch) specimen from St. Lucia, British West Indies. Photograph by John Tee-Van.

PLATE II.

Fig. 3. *Parathunnus atlanticus* (Lesson). 495 mm. (19½-inch) specimen from Bermuda. Photograph by John Tee-Van.

Fig. 4. *Parathunnus atlanticus* (Lesson). 263 mm. (10-1/3-inch) specimen from Bermuda. This is the smallest recorded specimen. Photograph by John Tee-Van.

PLATE III.

Fig. 5. *Neothunnus argentivittatus* (Cuvier and Valenciennes). Specimen from St. Helena. Copy of plate labelled *"Thynnus albacora,"* from Cunningham, *Proc. Zool. Soc. London,* 1910, p. 110, text-fig. 4.

Fig. 6. *Neothunnus argentivittatus* (Cuvier and Valenciennes). 555 mm. (22-inch) specimen from Bermuda. Photograph by John Tee-Van.

PLATE IV.

Fig. 7. *Neothunnus argentivittatus* (Cuvier and Valenciennes). 48-inch specimen weighing 45 pounds, taken at Bermuda by Mrs. W. B. Holler of Birmingham, Michigan. Photograph by David Knudsen.

PLATE V.

Fig. 8. *Neothunnus argentivittatus* (Cuvier and Valenciennes). 1,450 mm. (57-inch) specimen from Castries, St. Lucia, British West Indies. Photograph by John Tee-Van.

Fig. 9. *Neothunnus argentivittatus* (Cuvier and Valenciennes). Head of 1,450 mm. (57-inch) specimen from Castries, St. Lucia, British West Indies. Photograph by John Tee-Van.

PLATE VI.

Fig. 10. *Neothunnus argentivittatus* (Cuvier and Valenciennes). Swim-bladder of 1,450 mm. (57-inch) specimen from Castries, St. Lucia, British West Indies. Photograph by John Tee-Van.

Fig. 11. *Neothunnus argentivittatus* (Cuvier and Valenciennes). Caudal keels of 1,450 mm. (57-inch) specimen from Castries, St. Lucia, British West Indies. Photograph by John Tee-Van.

PLATE VII.

Fig. 12. *Neothunnus argentivittatus* (Cuvier and Valenciennes). 1,450 mm. (57-inch) fish being brought on board yacht at Castries, St. Lucia, British West Indies, showing type of native boat used for fishing for these giant fish. Photograph by John Tee-Van.

Fig. 13. Copy of original figure of Hans Sloane of the Madeiran albacore. (Sloane, Tab. 1, Fig. 1).
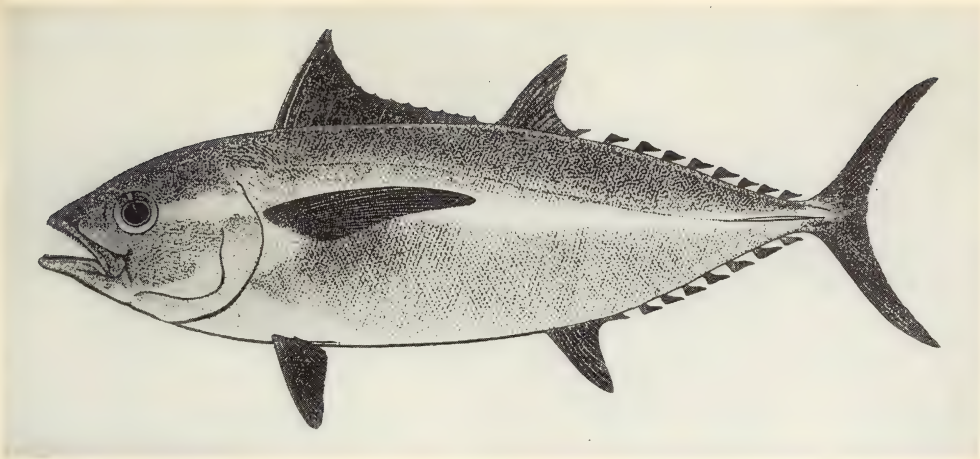
FIG. 1.
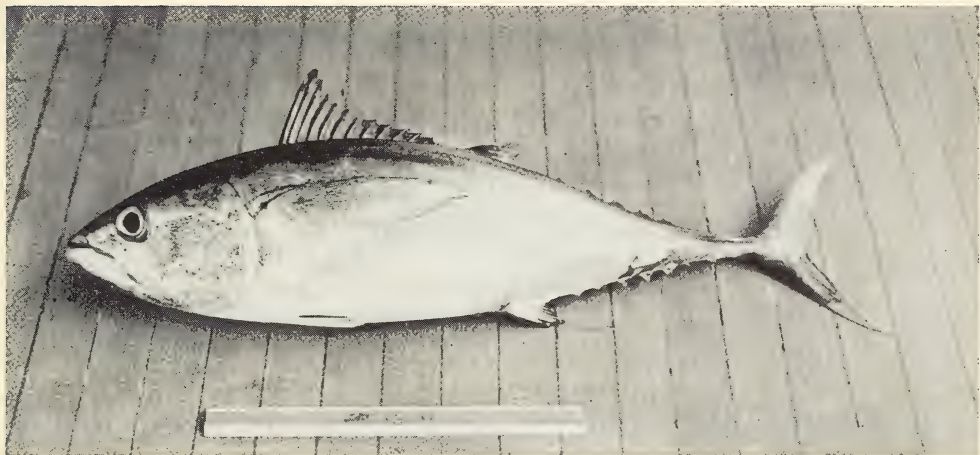
FIG. 2.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

FIG. 3.
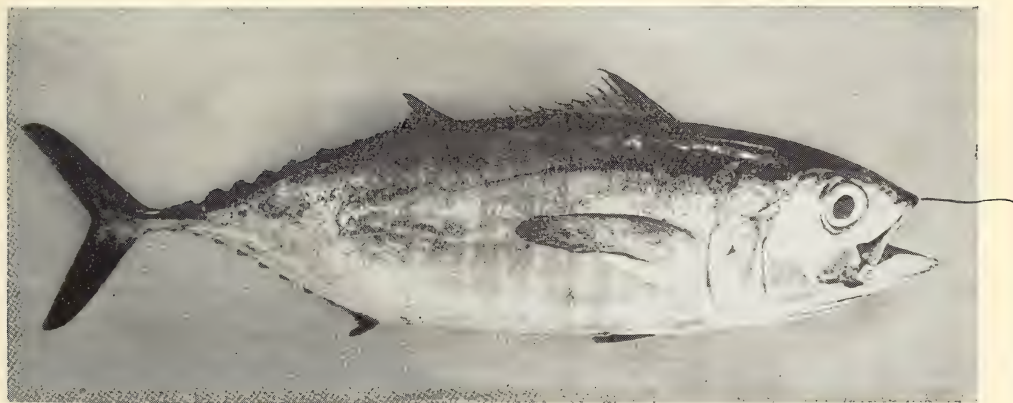
FIG. 4.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.
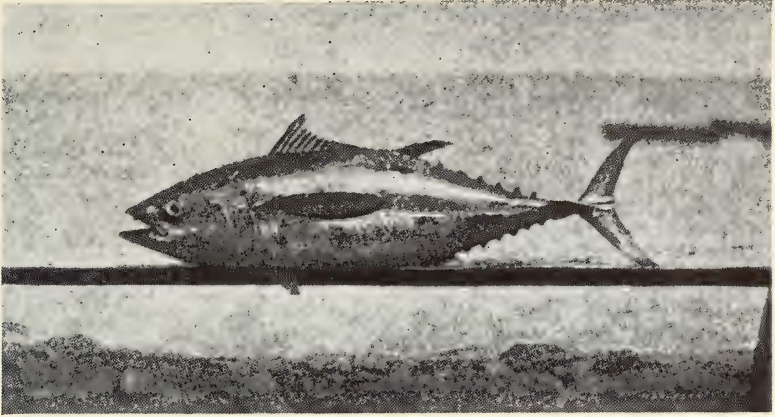
FIG. 5.
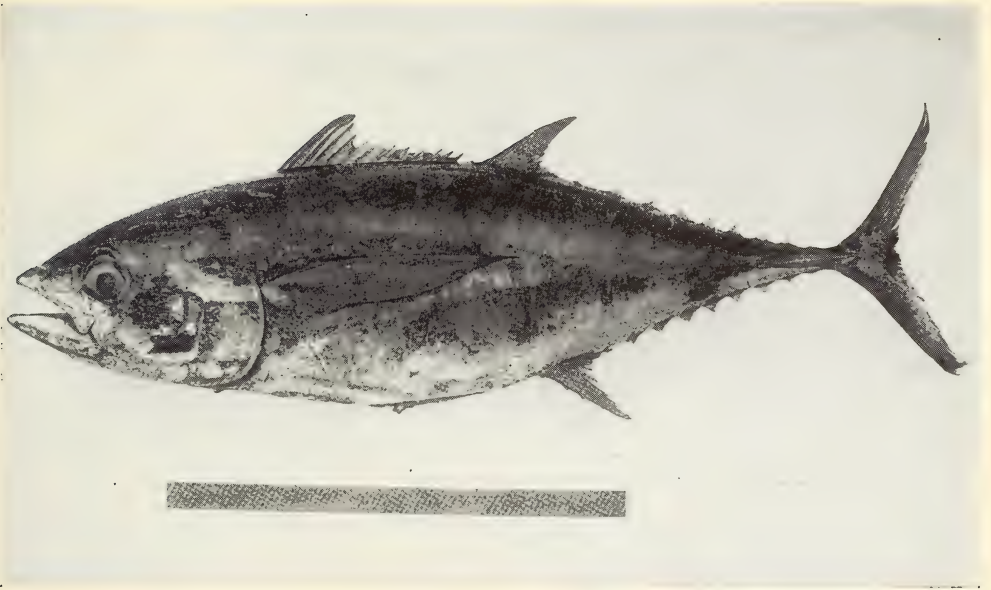
FIG. 6.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

FIG. 7.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

FIG. 8.
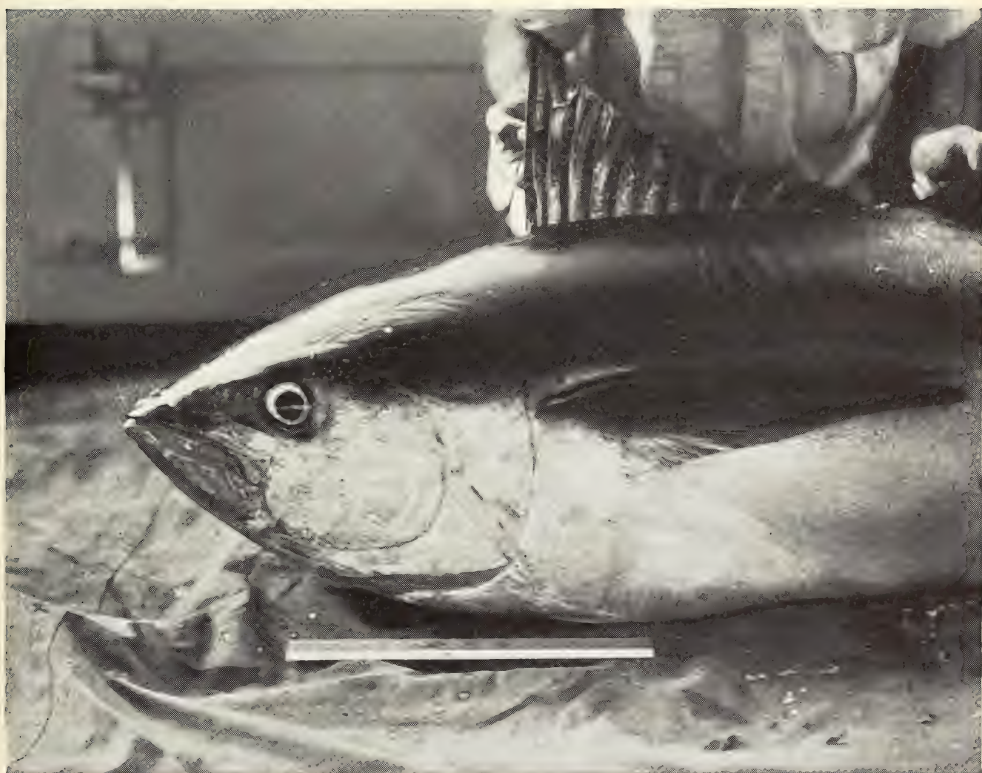
FIG. 9.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.
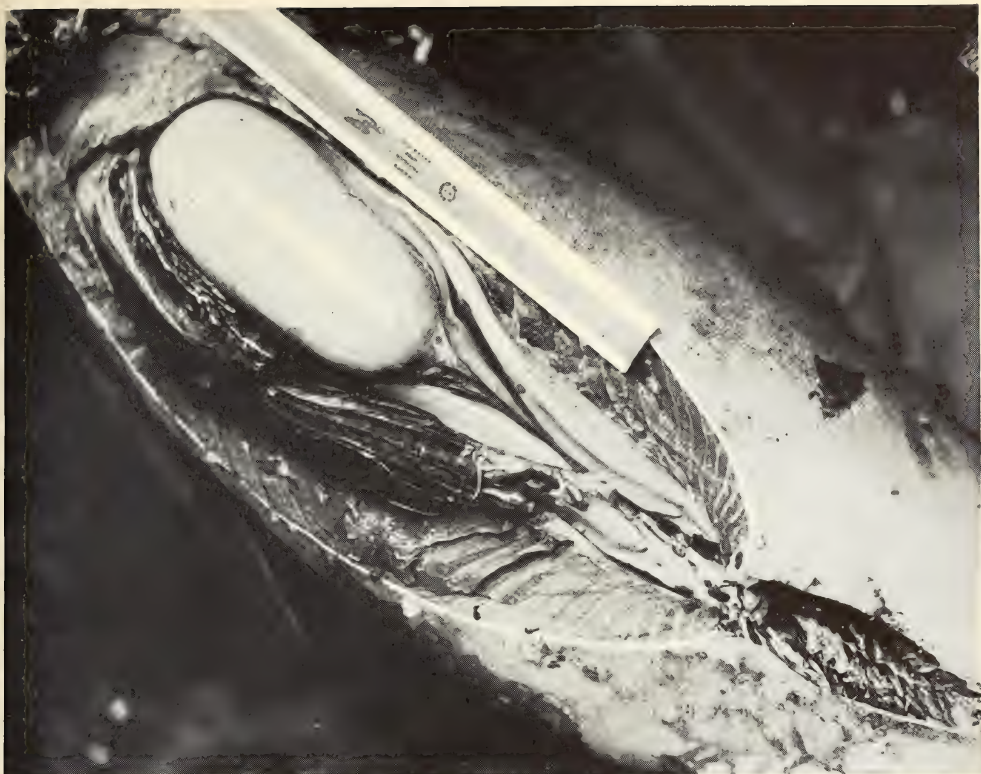
FIG. 10.
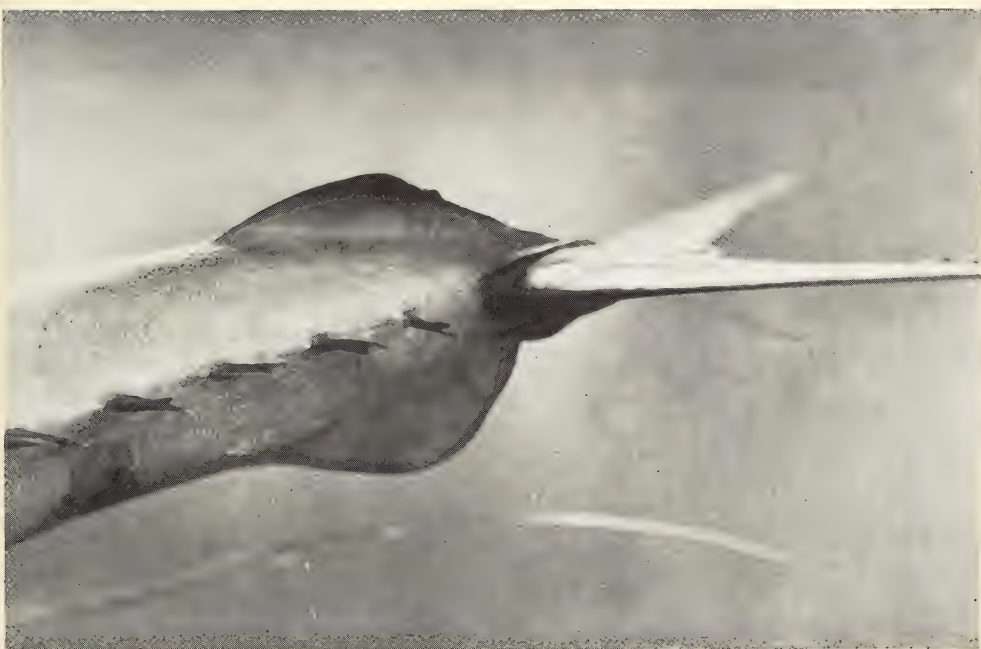
FIG. 11.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

FIG. 12.
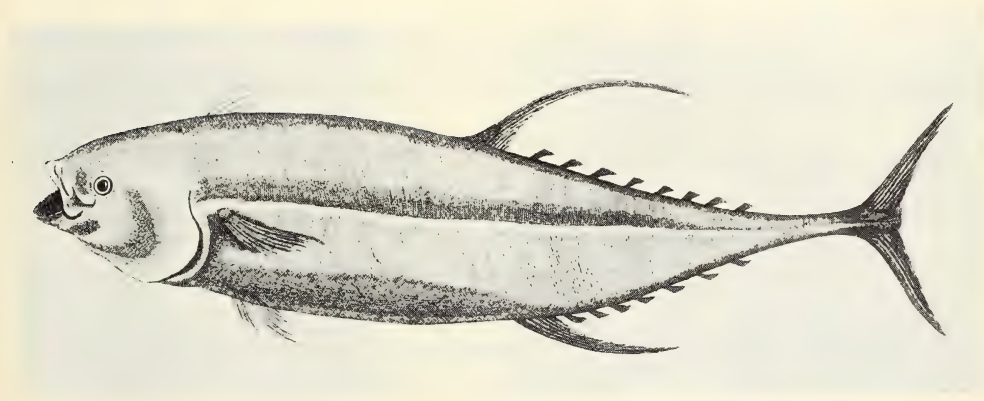
FIG. 13.

SYSTEMATIC NOTES ON BERMUDIAN AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

15.

Food of the Bermuda and West Indian Tunas of the Genera *Parathunnus* and *Neothunnus*[1].

WILLIAM BEEBE.

Director, Department of Tropical Research,
New York Zoological Society.

(Plates I-III).

OUTLINE.

INTRODUCTION.

Although these grand game fish are so widely distributed, and in certain localities actually abundant, almost nothing of an accurate character has been published in regard to the food of any species of tuna[2]. In paper after paper we find that they are credited with feeding on "small fishes such as herrings, sardines and anchovies." Other authorities aver they subsist almost entirely on Copepoda and similar constituents of pelagic plankton. As a matter of fact, the above-mentioned fish enter hardly at all into their diet, while Copepoda is almost the only general group of crustaceans which we have never recorded from tuna stomachs.

This examination of the stomachs of tuna has developed varied and unexpected side lines of interest. We have found rare or quite new species of fish and invertebrates; from the food alone we have been able to learn much of the fish fauna of certain areas, especially in depths of one hundred to three hundred fathoms, off Bermuda, which are so obstructed with coral reefs that neither net nor dredge can be used. For example, we have found that *Holocentrus meeki* Bean (1906) is the immature stage of *H. ascensionis*. We know by the food at what depths the tuna have fed, and whether they have been swimming and feeding solitarily, in pairs or in schools.

My thanks are due to Mr. Martin D. Burkenroad of the Peabody Museum for the determination of decapods taken from the stomachs.

Food of the Atlantic Black-finned Tuna, *Parathunnus*
atlanticus (Lesson).

Part I.

Bermuda Notes.

Summarizing the food of 58 black-finned tunas taken in Bermuda during 1935 and 1936, we find that seven phyla are represented, Coelenterata, Nemathelminthes, Platyhelminthes, Annelida, Mollusca, Arthropoda and Chordata. The three general groups most abundantly and frequently represented are fish, young crustaceans (especially squilla larvae) and squids. Twenty-nine species of fish have been differentiated, not counting hopelessly mutilated individuals, which, if they could be identified, would easily double the number of forms. Of the 29, 13 have to date been specifically identified. Of the 58 stomachs examined, the majority contained both invertebrates and fish. Seven, or 12%, were empty.

The following list shows the general types of food contained in the stomachs:

Type of Food	*No. of stomachs in which it occurred.*
Sargassum weed	4
Siphonophores	1
Worms	6
Gastropods	3
Pteropods	5
Cephalopods	31
Squilla young	16
Shrimps	20
Amphipods, crabs, etc.	25
Isospondyls	2
Non-Isospondyls	54
Unknown fish	17

We can hardly consider the tunas as herbivorous, yet in four stomachs were such amounts of sargassum weed that there is no doubt it was swallowed intentionally. The single siphonophore may very well be put down as accidental, perhaps included when the squilla or the squid was swallowed. Worms, too, are negligible, most of them being parasitic stomach nematodes.

The pteropods are an interesting although relatively unimportant item of diet. Four species have been found, *Cavolinia, Creseis, Cuvierina* and *Limacina,* one each in four occurrences, so this is obviously a casual element of food. It illustrates, however, what we will find emphasized in other groups, that organisms of remarkably small size are deliberately chosen. The few, very small gastropods were young, free-swimming phases, not yet settled down to a bottom life.

For relatively large size and frequency of occurrence, squids were far ahead of any other group of invertebrates, and equalled only by the group of fishes as a whole. Squids were found in 30 stomachs or more than 60% of those which contained food, and they totalled 96 individuals. Some were pelagic forms found in the upper layers of the ocean, but a considerable percentage were luminous inhabitants of quarter-mile or greater depths.

The most universal food of tunas both of the Atlantic and the Pacific is the young of squillas or stomatopods. There is not the slightest doubt of the deliberate search for and choice of these organisms. They occur in 16 stomachs, nearly one-third of the whole, and to the number of 907 individuals. From these tuna records we may be certain that squilla larvae

occur usually in swarms. In 5 out of the 16 the average was something over 2 squillas to a fish, but in the remaining instances the average was over 80 squillas in each case. Many of these tunas had been feeding near the surface, yet No. 24,513 which had undoubtedly been procuring its nutriment a quarter-mile down, had devoured 60 squilla larvae.

The hyperid amphipods *Oxycephalus* and *Phronima,* the euphausiid *Thysanopoda,* megalops and young swimming crabs were present, but in small numbers and widely distributed throughout many stomachs. Other hyperid amphipods occurred 10 times, one fish having swallowed 55. Single specimens were taken of two peneids, one being the rare larva, *Cerataspis monstrosa,* and the other an adult male *Funchalia villosa,* the third male of its subgenus ever reported.

Carideans were usually rare, but a new species of *Leptochela* occurred six times, in large numbers in every case. We counted 24, 34, 161, 144, 27 and 39, all of them being adult. The interesting thing is that the first four lots were from tunas all taken in mid-September, 1935, from the same locality and at the same time, so that there must have been a tremendous swarming of the shrimp. When diving seven fathoms down near Gurnet's Rock, I have often seen great misty clouds of crustaceans, usually mysids. In cases like this, it would hardly seem possible for the tuna to seize the organisms one by one. The fish must swim through the swarm, snapping right and left, and, as with all the other elements of tne food, swallowing the crustaceans whole. The two last lots of *Leptochela* were from fish equally closely associated in time and space, but taken on September 28. A species of *Palaemonella,* probably new, was present in two stomachs, and undescribed caridean post-larvae (Hippolytid?) occurred in three.

The fishes of the tuna food may, for convenience, be divided into three sections: first, the deep-sea element in tunas Nos. 24,512, 24,513 and 25,705; second, the fish which from September 4 to 28, 1935, are closely interlocked by their food; and third, all the other fish food. Considering these in reverse order, the third section includes scattered records of six fish used as food. A tuna taken July 18 had eaten a three-inch red-tailed triggerfish, *Xanthichthys ringens,* and a six-inch creolefish, *Paranthias furcifer.* September 14, a tuna caught well offshore had eaten three pomfrets, *Brama raii,* measuring little more than an inch each. October 9 we took an inchling trigger, *Monocanthus tuckeri,* from another tuna.

A butterflyfish, *Chaetodon,* only half an inch long, was among the food of a tuna taken in March, 1936. Four other tunas captured at this time, and within a short time of each other, had been feeding on anchovies, *Sardinella anchovia.* This quartet of tunas had eaten 55, 1, 2 and 16 respectively. The anchovy, unlike its relations, the pilchards and green fry, is rare close inshore at Bermuda, but very abundant offshore in mid-depths.

On September 4, 1935, my good friend and very skilful angler, Mrs. E. T. Weir, went out after tuna, and two miles southwest of Nonsuch Island sighted a large school leaping and playing about at the surface. A conservative estimate was about three hundred and they all appeared to be in the neighborhood of two feet long. Trawling back and forth, Mrs. Weir caught three and I found the food of this trio intensely interesting. They were the beginning of a series of seventeen, all interrelated through the similarity of their food, all taken in the three and a half weeks' time between September 4 and 28, 1935.

This general area from which they came is the almost unexplored zone which lies between the shallow Bermuda shore waters (where, down to fifty feet, we can walk about and observe by means of the diving helmet) and the outer abyssal depths, where the bottom, being of soft, relatively level ooze, is dredgeable. The prevalence of rough, jagged limestone covered with living coral makes the mid-zone wholly impossible for either trawling

net or dredge.   In the old *Challenger* Reports of sixty-three years ago, we find that six soundings or dredges were made within this coral reef zone directly south of Nonsuch Island where the tuna are feeding today.   We read of empty dredges or "in heaving in, the line carried away through chafing on hard ground."   A short distance farther out, but still in the coral zone, at Station 33, the dredge came up unharmed with a catch so rich that the amazing fauna of this difficult ground was evident.   The summary reads: "Excluding Protozoa, over 80 specimens of invertebrates were obtained at this station, belonging to about 70 species, of which 22 are new to science, including representatives of 3 new genera; 12 of the new species and 1 new genus were not obtained elsewhere."   In addition to this list, 22 pteropods and heteropods, 152 Foraminifera and 83 diatoms were found.   So the total for this one dredge haul was 337 species of organisms.

When I examined the stomach of the first of these tunas, I realized that the contents were alien to the shallow waters of Bermuda along shore, and yet had nothing in common with the fauna of the deeper, offshore areas. And I will here anticipate another discovery which was emphasized again and again, that these great fish had almost without exception been feeding close to the bottom.   Somehow, I had never visualized these swift, pelagic beings as searching over, around and perhaps in the gorges and arches of the eroded limestone.   But for that matter I had never thought to find such small, spiny organisms as squilla larvae dominant in their diet.

During the few nights preceding the first catch of these September tunas, we had as usual netted many fish attracted to our New Nonsuch wharf by the submerged and the ultra-violet lights.   During this period we caught a number of the rarest squirrelfish known to Bermuda.   The type of *Holocentrus meeki* was taken only three miles from our wharf, near St. David's Island thirty years ago.   On Nonsuch Island, we had once captured an additional single specimen.   Here were six taken in one evening, and in the stomach of the first tuna were no fewer than sixty of the same squirrelfish, in excellent condition.   Pl. III, Fig. 5, shows fifty of these, so little affected by the gastric juices that even the colors were faintly evident.   I was amazed to see this unexpected mass of exceedingly rare fish.

We kept several of those taken at the wharf alive in aquariums, and carefully watched them.   Before our eyes, little by little, in the course of several weeks they changed from *Holocentrus meeki* to the common squirrelfish, *Holocentrus ascensionis*.   The soft dorsal and anal fins increased in height, the depth of the body became greater, the greenish metallic tints gave place to rose and scarlet, and the abrupt, unlovely profile of the caudal peduncle slowly took form in our aquariums.   There was no doubt about the fact that *meeki* is the immature stage of *ascensionis*.   Large, brilliantly colored individuals of the latter species lived in cracks and crevices among the rocks about our wharf, but we had never before seen the young, and had no idea where they bred.   Even in their habits and actions as well as in physical attributes the younger ones were unlike the adults.   They kept in mid-water, well above the bottom, and were extremely wary, dashing here and there, often pursued and driven off by our wharf's habitués, their elder brethren.

There is another less common species of squirrelfish, the black-barred, *Holocentrus vexillarius,* slightly deeper in the body, darker in shade, with fewer dorsal spines and rays and only about half as many gill-rakers as the common form. There is also the very lovely, lesser butterflyfish, *Chaetodon sedentarius,* which we count as a rare fish in Bermuda, in comparison with three other species of the same genus. With this fore-knowledge of these three forms in mind, let us prepare a table of the food of our seventeen tunas, all taken within the period of two weeks, one to two miles off Nonsuch, and see what we can learn from it (Table I).

TABLE I.

Food of Bermuda specimens of *Parathunnus atlanticus* taken in September.

Tuna No.	17	18	19	23	24	25	26	27	34	35	36	37	38	39	40	41	42	Total
September	4	4	4	12	12	12	12	21	27	27	27	28	28	28	28	28	28	
Sargassum weed													1	1				
Holocentrus ascensionis	60	66	14	18	4	2	1	44	13	3	2	52						277
Holocentrus vexillarius	3	4	1								8	1	64	71	80	73	87	392
Chaetodon sedentarius	1		1							1	2	3	2	1	18	18	5	52
Leptochela sp. nov						24	34	161	144						27	39		429
Squids	1	4	3	1				7	4	10						2	2	34
Squilla yg		33	12			210				65				71				391
Serranid											1							
Parrotfish											2							
Wrasse, incl. 1 *Xyrichthys*											4							
Exonautes rubescens																	1	
Melanostomiatid-like fish								1										
Flounder (*Etropus?*)								1										
Acanthurus sp								1										
Creseis								1										
Limacina								1										
Yg. Gastropods								2										
Oxycephalus								1	1									
Hyperids								5							1			
Glaucothoe yg															1			
Palaemonella sp. nov?															4	2		
Caridean yg. (Hippolytid?)										2					1		1	
Megalops			1												2		2	

Let us consider first the common squirrelfish, *H. ascensionis* (which for a time we thought was *H. meeki*). We find that it forms a large proportion of the food of the first twelve tunas, extending over the entire period of three and a half weeks. Although there are two tunaless intervals during this time, one of a week and the other of ten days, yet the supply of young squirrelfish never diminished. From a single individual to as many as 66 occur in a single stomach, the average eaten by each fish being 23. Here is a total of 277 squirrelfish, all of exactly the same stage of growth, all measuring two and a half inches in length (Fig. 5).

This paper purports to be concerned with consideration of the direct elements of food of tunas, but before we leave this species of *Holocentrus*, I want to carry them on to the indirect victualization of these fishes. I select three young squirrelfish at random from among the 60 in the first tuna's stomach and, in turn, examine their stomachs.

Stomachs of *H. ascensionis*

	A.	B.	C.
Candacia aethiopica	15	21	153
Other copepods	7	5	6
Ostracods	6	..	..
Euphausiids	..	1	..
Shrimps	..	2	..
Zoeas	8	6	7

Here in three out of 60 ingested fish were 237 organisms in perfect condition, giving a still more intensive visualization of the life of the

isolated mid-zone. And in the stomachs of several of the *Candacia* were radiolarians and diatoms, and so *ad infinitum.* This gives at least a more vital conception as to what means we must resort if we are ever to get farther in the study of these relatively inaccessible regions, than through conventionally usual methods of direct observation.

The stomachal distribution of the black-barred squirrelfish, *H. vexillarius,* is enlightening. The first three tuna had caught 3, 4 and 1 respectively, showing that these fish were about on September 4, after which not an individual appeared until 23 days had passed, when a tuna dined off both species. If we had had only this one fish, the significance of the reappearance of *vexillarius* would not have been apparent, but the following day and the same place yielded six tuna which were filled to repletion with *vexillarius,* while *ascensionis,* except for one fish, vanished forever from the diet, although they kept coming in small numbers to the night lights at our wharf. In the 5 tunas which had eaten only *vexillarius* were 375 individuals, an average of 75 squirrelfish to a tuna.

Like *vexillarius,* one or two of the rare butterflyfish, *Chaetodon sedentarius,* were found and devoured on September 4, and then reappeared on the 27th. On this and the following day, they must have been far from rare around the deep coral reefs of the tunas' feeding grounds, for 52 were divided among 8 tunas, two of which had found and accounted for 18 each. These butterflyfish will not take a hook, however small, and no trap can be lowered and recovered in these waters, so were it not for the tuna gourmands we should never have known of their abundance anywhere near Bermuda. Chaetodonts are essentially reef fish, swimming in and out among the branches and fans, and the young especially are never found far from shelter. Yet there were a half hundred youngsters, none over an inch in length, fallen victims to fish which, according to our preconceptions, should find their living in swift pursuit of organisms in mid- and upper zones.

Additional evidence of the frequent bottom feeding of tunas is found in one captured on September 27, which, in addition to both species of squirrelfish and chaetodonts, had included 4 wrasse and 2 parrotfish in its diet.

I have already spoken in general of squids, squilla larvae and carideans, and in the present consideration it is necessary only to look at the chart to see how the relation of these organisms to other food elements holds good for these 17 as for the entire 58 tunas. Thirty-four squids were eaten by 9 of the 17 tunas, with an average of less than 4 each; 391 squilla larvae were found in the coral zone by 5 tunas, each averaging 78; and specimens of the new *Leptochela,* as I have already mentioned, were present to the number of 429. Other items of diet of the 17 fish were negligible, but the food of tuna Number 27, taken on September 12, stands out by itself. The fish was captured in company with four of its fellows and like them had found *H. ascensionis* eminently to its taste, having pursued and captured 44, which if laid end to end would extend a distance of ten feet! These were, however, packed, sardine-wise, side by side within the tuna. With them were 13 other organisms of especial significance. These included two species of pteropods, an *Oxycephalus,* a small Melanostomiatid-like fish and a young free-swimming flounder. These and a few others come to the surface of the ocean at night, but in the day are found relatively deep and well offshore. So this individual fish must have done part of its feeding by itself and farther down and out at sea, or the night before. The fresh condition of the food indicated the former course as the more probable one. One more link with the habitat of the young squirrelfish and the butterflyfish was a single surgeon fish in its food.

On August 7, 1935, Mr. Christianson brought us two tunas, caught almost simultaneously, three miles southeast of Nonsuch Island. This is be-

yond the shallow, coral-lined waters of the coastal area, and over the abyssal depths of the deep open sea itself. Tuna are so often seen and taken in pairs that it appears reasonable to assume a definite relation between the two. In this case the male weighed sixteen pounds and the female twelve. They were typical black-finned tuna.

Although they were caught at the surface with white feather jigs, the first glance at the food showed that very recently they had been feeding at great depths. The food was quite fresh and the tuna must have come to the surface with a rush and immediately seized the feather jigs, far above their zone of feeding. Between them, these tuna had eaten thirty deep-sea fish, some quite new, others exceedingly rare, and several of the world's record size. In addition they had swallowed a dozen luminous squids and more than three score other creatures of the black abysses. The light organs of all were plainly visible, together with the typical scarlet and black coloration of inhabitants of the sunless depths. None of these hundred-odd organisms would ever, of its own free will, have risen even into the dimly-lighted regions of mid-water. The average depth at which they thrive, and must have been caught and devoured, is a half mile or more below the surface.

I submit photographs of the contents of these two stomachs as the contents were removed and roughly sorted, and opposite each of these two figures are two others showing the accurate restorations of every item of diet. In Pl. I, Fig. 2, we see at the top 23 lanternfish, *Diaphus effulgens*, then an oval-bodied pomfret or *Brama raii*, and to the left an unknown, short-toothed, gempylid-like fish. Below is a fierce-looking *Alepisaurus* or lancet-fish with a gigantic sail-fin. Next come two sabre-toothed *Omosudis lowii*, the larger a world's record for size (180 mm.). Near the bottom are three silver hatchetfish, *Argyropelecus aculeatus*, and scattered about we count 9 squid covered with luminous organs of various colors.

The second plate of reconstruction (Pl. II, Fig. 4) shows what the female tuna had for dinner on this particular seventh of August, and proves that she must have eaten at the same level and time as her mate. There are fewer lanternfish, in fact only three, and these are of a different species, *Diaphus rafinesquei*, and we counted 60 larval squillas. This tuna had also devoured exceedingly rare deep-sea fish. At the top is a new species, gempylid-like, with saw teeth; then two most interesting members of the family Trichiuridae or cutlassfish, a family wholly new to Bermuda which we have never taken in any of our fifteen hundred nets. The name of this fish, brought to us from a great depth by the tuna, is *Benthodesmus atlanticus*.

Below these are five individuals of a probably new species of *Paralepis* or ocean pikelet. Finally there are three luminous shrimps which were in the stomach of this tuna. The relative sizes are indicated on the figures. These deep-sea fish are larger than any fish which we have found in tunas feeding at higher levels.

Table II shows, in diagrammatic form, the direct and indirect food of these two deep-feeding tuna.

The stomach of the third and remaining tuna which showed indubitable evidence of having fed, in part, at a considerable depth was sent to us through the courtesy of Mr. Robert Blackman. It was caught near Bermuda early in the spring of 1936, and contained the following organisms: one 170 mm. *Avocettina infans*, which is one of the rarest deep-sea eels; two specimens of the lanternfish, *Myctophum hygomi;* one *Sardinella anchovia;* two squids, one of which had light organs; and one squilla larva.

TABLE II.

Direct and indirect food of two specimens of *Parathunnus atlanticus*.

TUNA NO. 24,512

- **3 *Argyropelecus aculeatus***
  - 1 Shrimp
  - 8 Ostracods
- **23 *Diaphus effulgens***
  - 1 *Cyclothone* sp.
  - 3 Shrimp
  - 7 Hyperids
  - 1 Gammarid
  - 1 Ostracod
  - 2 Squids
  - 1 Sagitta
- **2 *Omosudis lowii***
  - 1 Unknown Fish
- **1 *Alepisaurus* sp.**
  - 9 Luminous Squids
- **1 *Gempylid***
  - 1 Hyperid
- **1 *Brama raii***

TUNA NO. 24,513

- **3 *Diaphus rafinesquei***
  - 1 Shrimp
  - 3 Hyperids
  - 1 Gammarid
- **5 *Paralepis* sp.**
  - 1 *Cyclothone* sp.
  - 1 Larval Fish
  - 1 Squid
- **2 *Benthodesmus atlanticus***
  - 2 Shrimp
  - 1 Squid
- **3 Gempylids, (2 species)**
  - 1 Fish
  - 1 Squid
- **60 Squilla yg.**
- **3 Squids**

PART II.

FLORIDA NOTES.

The data from this region is very scanty and refers to only two individual *Parathunnus atlanticus*, kindly sent me by Mr. Frederick Church. Both were found in the stomach of a Blue Marlin, *Makaira nigricans ampla* (Poey), which was more than ten feet long and weighed 304 pounds. The tuna weighed respectively 7 and 4 pounds. The former had eaten a single *Sardinella* of 55 mm. The second tuna ran true to form and though there were only two small organisms in its stomach, they were both squilla larvae.

PART III.

ST. LUCIA AND TOBAGO NOTES.

A pair of tuna taken at St. Lucia and 20 at Tobago show such similar stomach contents that I am considering them together. In our work at St. Lucia we have to thank Major William Lambert for many courtesies.

A number of leaves of some tropical tree found in one fish is the sum total of vegetable elements. Nine groups of invertebrates are present, of which only three are dominant; megalops with a total of 114 in 15 tunas, 308 squilla larvae in 19 stomachs, and 43 squids eaten by 7 individuals. Eleven genera of fish were identified in 11 tuna, besides many other small ones not yet named. All occur singly or not more than 4 to a stomach except *Anchoviella* (18), *Polynemus virginicus* (10), *Monocanthus* (12) and puffers (8). The others are *Harengula*, *Hemirhamphus*, *Fistularia serrata*, *Jenkinsia*, *Decapterus macarellus*, *Selene vomer* and *Lactophrys*. Except for the *Decapterus*, which was 6 inches long, all are two inches or under, and the majority are an inch or less. Their spiny character and almost wholly bottom habitat are also evident.

We once recorded *Rhomboplites aurorubens* from the stomach of a tuna taken near Haiti.

FOOD OF THE ATLANTIC YELLOW-FINNED TUNA, *Neothunnus argentivittatus* (Cuv. and Val.).

As far as I know there has been no attempt at recording any details with regard to the food of this important commercial and game fish. The appended table presents a list of the stomach contents of eight individuals, one from Bermuda and seven from St. Lucia, the latter taken in the Channel between that island and Martinique. The Bermuda yellow-fin had swallowed only a few fresh fronds of Sargassum weed, and, strangely enough, leaves and bark were found in the stomachs of two of the others.

Squids were found in five out of the seven St. Lucia specimens. Ten species of fish have been identified and those which remain unknown would about double this number. *Oxyporhamphus* is an interesting primitive form of flyingfish with very small pectorals, and was unquestionably caught near the surface, while *Gonostoma*, the only representative of a deep-sea family found in the food of the yellow-fins, was probably swallowed several hundred fathoms down.

St. Lucia yellow-finned tuna No. 24,689 had the most interesting food. The invertebrate proportion was negligible, consisting of a single squid mandible, and 9 megalops. The fish totalled 58 individuals of at least 6 species, and comprising 4 puffers, 1 leathery filefish, 1 red-tailed triggerfish, 9 unidentified triggers and 42 flying gurnards. The average length of the puffers is 81 mm., of the triggerfish 31 mm., and of the two score gurnards 45 mm.

A general survey of the food of this individual reveals several unusual facts which are characteristic of tunas of several species, both in the Atlantic and Pacific Oceans. Here is a fish almost six feet in length (1,450 mm.) with a correspondingly good-sized mouth, yet which has chosen to swallow 58 fish averaging barely two inches in length. Also it would be difficult to choose a lot of fish less appetizing than these puffers, triggers, turbots and gurnards. They epitomize spininess in respect to skin, opercles and fin elements, and correlated with this supposedly protective armor the actual flesh and muscle necessary for swift movement are much less developed than in more ordinary fish.

This choice must be deliberate when we consider the amazing speed of these tunas, the ample size of their mouths and the abundance of smooth-skinned, thick-fleshed fish of all sizes. The swift-moving white feather jig would seem to have nothing in common with triggers, puffers and squilla larvae, yet this white surface lure is pursued and seized with eagerness and ease. Among the spiny organisms which dominated the tunas' diet were squillas, euphausiids, shrimps, megalops, *Hyporhamphus, Oxyporhamphus, Holocentrus, Cephalacanthus, Xanthichthys, Balistes,* and *Monacanthus,* while squids were the only smooth-skinned creatures of any numerical importance (Table III).

TABLE III.

Food of yellow-finned tuna: *Neothunnus argentivittatus.*

Cat. No. of Tuna	24,682	24,683	24,689	24,690	24,691	....	....	25,206
Place	St. Lucia	St. Lucia	St. Lucia	St. Lucia	St. Lucia	St. Lucia	St. Lucia	Bermuda
Length	645	690	1450	1360	....	....	....	555
Weight	12	16	140	....	....	....	....	8
Sex	Male	Male	Male	Male	Male	....	....	Male
Sargassum Weed	....	....	....	....	....	....	....	Few fronds
Leaf	....	1	....	....	....	....	....	....
Bark	....	....	1	....	....	....	....	....
Squid	....	....	1	5	5	2	6	....
Squilla larvae	2	26	....	2	....	....	....	....
Euphausiids	....	3	....	....	....	....	....	....
Shrimps	....	....	....	....	1	....	....	....
Megalops	....	....	9	55	1	....	....	....
Sardinella anchovia	....	....	....	....	....	....	1	....
Gonostoma sp.	....	....	....	....	2	....	....	....
Hyporhamphus unifasciatus	....	....	1	....	....	....	....	....
Oxyporhamphus micropterus	....	....	....	1	....	....	....	....
Holocentrus ascensionis	....	....	....	1	....	4	10	....
Decapterus macerellus	....	1	....	....	1	....	....	....
Cephalacanthus volitans	....	....	42	2	....	....	....	....
Xanthichthys ringens	....	....	1	....	....	....	....	....
Balistes forcipatus	....	....	1	....	....	....	....	....
Monacanthus hispidus	....	....	1	....	....	....	....	....
Sphaeroides spengleri	....	....	4	....	....	....	....	....
Unknown flying fish	....	....	....	....	....	1	....	....
Unknown triggerfish	....	....	9	1	....	....	....	....
Unknown fish	2	....	....	1	8	1	2	....

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Contents of the stomach of a 16 pound male, black-finned tuna, *Parathunnus atlanticus*, Catalogue No. 24,512, taken at the surface south of Nonsuch Island, Bermuda, August 7, 1935. Both the fish and the invertebrates are deep-sea forms, relatively fresh and quite recognizable.

Fig. 2. Restoration of the deep-sea fish and invertebrate tuna food shown in Fig. 1. There are 42 organisms including 23 *Diaphus refulgens*, 1 *Brama raii*, 1 short-toothed gempylid, 1 *Alepisaurus* sp., 2 *Omosudis lowii*, 3 *Argyropelecus aculeatus*, 1 unidentified triangular-toothed fish, 1 hyperid amphipod and 9 luminous squid. (Drawing by George Swanson).

PLATE II.

Fig. 3. Contents of the stomach of a 12 pound female *Parathunnus atlanticus*, Catalogue No. 24,513, taken at the same time and place as No. 24,512.

Fig. 4. Restoration of the deep-sea food of the female tuna shown in Fig. 3. Sixty-seven abyssal organisms including 1 saw-toothed gempylid, 2 *Benthodesmus atlanticus*, 2 short-toothed gempylids, 5 *Paralepis* sp., 3 *Diaphus rafinesquei*, 3 luminous squids, 51 squilla larvae. (Drawing by George Swanson).

PLATE III.

Fig. 5. Fifty out of 60 squirrelfish, *Holocentrus ascensionis*, taken from stomach of black-finned tuna, *Parathunnus atlanticus*, Catalogue No. 24,558.
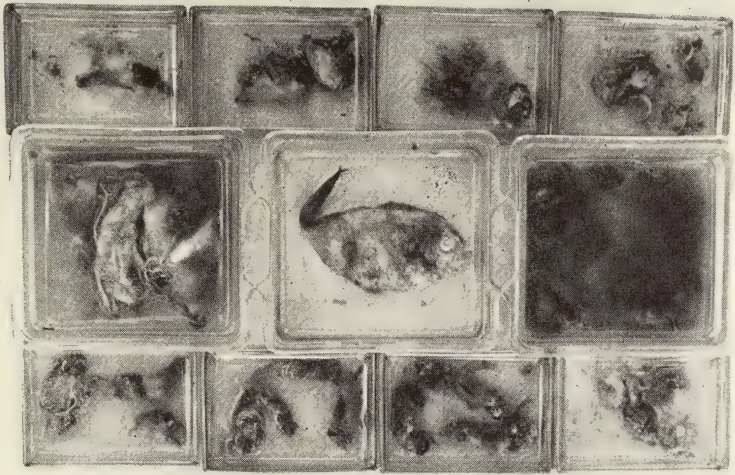
FIG. 1.
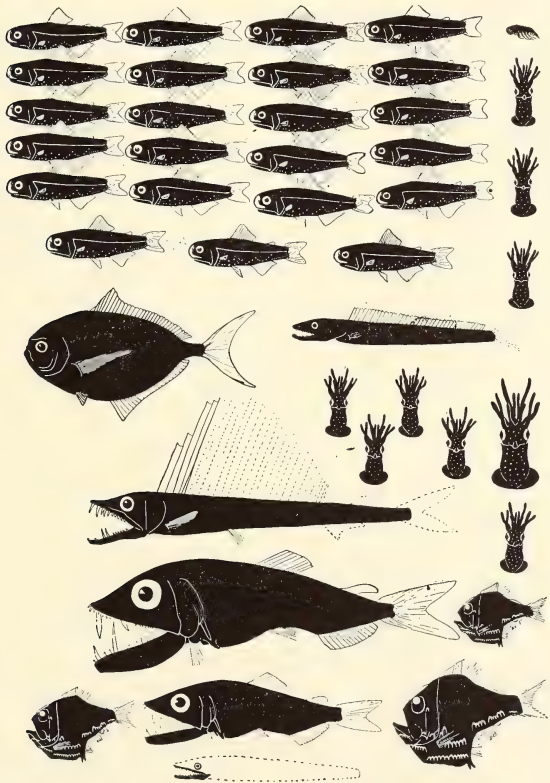
FIG. 2.

FOOD OF THE BERMUDA AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

PLATE II.
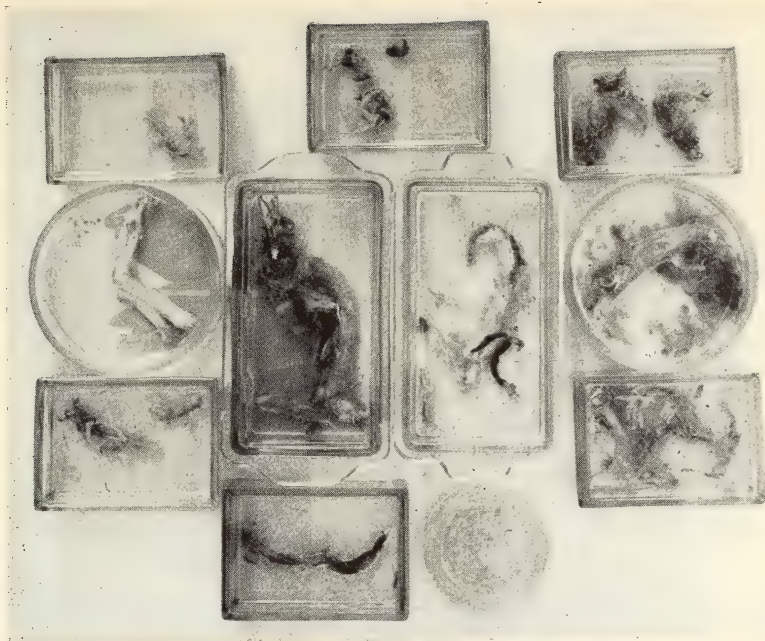
FIG. 3.

FIG. 4.

FOOD OF THE BERMUDA AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

FIG. 5.

FOOD OF THE BERMUDA AND WEST INDIAN TUNAS OF THE
GENERA PARATHUNNUS AND NEOTHUNNUS.

16.

Notes on the Biology and Ecology of Giant Tuna, *Thunnus thynnus* Linnaeus, Observed at Portland, Maine[1].

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New York Zoological Society.*

(Plate I; Text-figure 1).

CONTENTS.

INTRODUCTION.

The material for the following paper was gathered during the latter part of July, 1936, at Portland, Maine. For their unfailing cooperation, I wish to express my thanks to Mr. George L. Ratcliffe, President of the Portland Fish Co., to Dr. J. S. Jamieson of the same city, and to Mr. Walter H. Rich, Portland agent of the U. S. Bureau of Fisheries.

My thanks are also due to Mr. John Tee-Van of the New York Zoological Society and to Mr. Martin D. Burkenroad of the Peabody Museum for determinations of food samples, and to Dr. William Beebe for initiation and supervision of the work.

MATERIALS AND METHODS.

A total of 34 newly-caught tunas was examined, ranging from 41 inches in standard length and 65 pounds in weight (undressed), to 97 inches and

860 pounds. Gill-raker counts and food diagnoses were made in every case, the sex was determined in all but four, and partial or complete measurements and counts were secured from 10 specimens.

The methods of harpooning the tuna were observed by accompanying a fishing boat to sea, and in this way color notes of two living specimens were obtained and parasites preserved.

The giant tuna or horse mackerel are fairly common just outside Casco Bay during the summer months, and their capture is becoming an industry of increasing importance. Except for the few specimens which are caught by sportsmen on rod and reel, all of the tuna taken are harpooned by the native fishermen. The fishing launches, twenty to thirty-five feet in length, are each rigged with a platform or "pulpit" in the bow, and from here the harpooner makes his strike. Manned by a motorman and a single fisherman, the boats leave the wharf early in the morning, run straight out to the mouth of Casco Bay, and spend the day searching for tuna schools. While the fish are often found along the very entrance to the Bay, they must sometimes be followed far out to sea, 15 or 20 miles from the dock. When fish are sighted, the motorman approaches the school and follows it, manoeuvering to give the harpooner in the bow a chance to strike with the 12- or 15-foot "pike." Sometimes he must cast the pole as much as 25 feet or more, or submerge its full length under water. The largest fish taken during my stay (860 pounds) was harpooned as it swam at least 15 feet in advance of the bow and an equal distance under water. Small fish are usually brought alongside with scarcely any struggle, while large specimens sometimes fight several hours. Often no fish at all are caught by a given boat during the day, while at other times eight or ten will be taken.

For a complete account of the tuna fisheries of Maine, as well as for data on the numbers and weights of tuna caught during several recent seasons, see "The Horse Mackerel (Tuna) Fishery of Maine;" Department of Commerce, Bureau of Fisheries, Mem. S. 339, 1935, by Walter H. Rich.

DESCRIPTION OF *Thunnus thynnus* L., BASED ON SPECIMENS STUDIED AT PORTLAND.

COLORS: (From two specimens measuring 49 and 96.5 inches, standard length [ca. 100 and 860 pounds, respectively], examined at sea when caught; the smaller fought scarcely five minutes, and was very active when lifted into the boat, while the larger struggled nearly two hours and was almost dead upon examination, yet there was no essential color difference between the two. However, the color in both cases changed and faded entirely after ten minutes in the air).

Body: Dorsal surface blackish-bronze as far down as the dorsal margin of the eye or slightly lower; adjoining this a longitudinal stripe of bluish bronze running entire length of body and extending as low as the level of lower margin of pectoral fin base; rest of body silver. At death, the dorsal surface changed to greenish before losing color and becoming uniformly dark; the lateral stripe became brownish, then inconspicuous; and the ventral surface turned faintly violet, then dead white. Iris bronze.

Fins: Pectoral and caudal very dark, almost black; second dorsal silver gray, darkening at death; anal paler; second dorsal lobe and anal lobe with a narrow greenish-yellow stripe close to posterior margin and extending out to tip of lobe. This stripe persisted hours after death, was identical in all specimens examined on the wharf, and was invariably paler and greener than the finlets. Finlets always bright golden yellow, the color persisting.

MEASUREMENTS AND COUNTS: The data given below were compiled from measurements and counts made upon ten specimens. Their standard lengths and undressed weights were as follows:

No.	Standard Length			Weight
1.	1046 mm.	(41	in.)	65 lbs.
2.	1250 "	(49	")	ca. 105 "
3.	1658 "	(65	")	244 "
4.	1691 "	(66.3	")	189 "
5.	1900 "	(74.5	")	ca. 550 "
6.	2015 "	(79	")	ca. 600 "
7.	2142 "	(84	")	ca. 700 "
8.	2410 "	(94.5	")	ca. 700 "
9.	2460 "	(96.5	")	860 "
10.	2474 "	(97	")	772 "

External: Depth in standard length 2.8 to 3.3; head in length 3.2 to 3.9; eye in head 7.7 to 10.7; snout in head 2.3 to 3; tip of snout to middle of eye in head 2 to 2.5; maxillary in head 2.4 to 2.7; interorbital in head 1.9 to 2.8; snout to pectoral in length 3 to 3.5; snout to pelvic in length 3.1 to 3.3; snout to first dorsal in length 2.9 to 3.4; snout to second dorsal in length 1.7 to 1.8; snout to anal in length 1.4 to 1.6; height of first dorsal fin in head 2.3 to 2.6; height of second dorsal fin in head 1.6 to 2.4; height of anal fin in head 1.9 to 2.4; pectoral fin length in head 1.4 to 1.9; end of pectoral fin under 9th to 12th dorsal spine; caudal length in length 6.3 to 10.0; caudal spread in length 2.8 to 3.2. Pectoral rays I, 31 to I, 33; dorsal count XIV + I,11 + 9 to 11; anal count I,10 to 11 + 8 to 10. Gill-rakers 11—25 to 14—27 (see below). In every case the anal origin was distinctly behind the insertion of the last dorsal ray.

Internal: Length of stomach in length 3.9 to 5.6; length of longest liver lobe in length 7.5 to 10.4; liver unspotted, of four major lobes and a varying number of small lobes; length of caeca sac in length 4.3 to 5.2; length of testicle in length 2.4 to 2.8 (latter in small specimens).
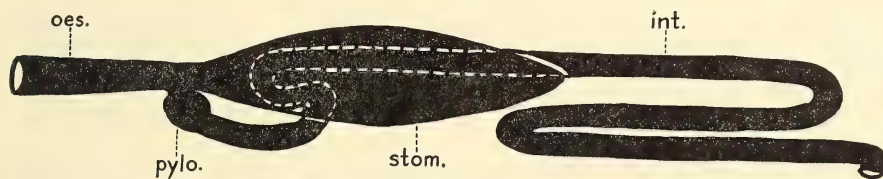
Text-figure 1.

The alimentary canal of a young specimen of *Thunnus thynnus* (standard length 41 in., weight 65 lbs.) taken at Portland, Maine. *Oes.*, oesophagus; *pylo.*, pylorus; *stom.*, stomach; *int.*, intestine. (x 1/5).

GILL-RAKER COUNTS: The gill arches of 34 specimens were examined, of which 13 had both sides intact, the others having been damaged during the dressing of the fish. Of these 13, only four specimens had the same gill-raker count on both sides. As will be seen from the following table of frequencies, the most usual counts were 13—25 and 13—26, while the extremes ranged from 11—25 and 12—24 to 14—27, giving a total of 36 to 41 gill-rakers on the first branchial arch. In the cases where the count was unequal on the two sides, the largest number occurred indiscriminately on either right or left side. Broken arches, in which only the upper or lower count could be taken, are omitted from the table.

Gill-raker Count	Frequency
11—25	1
12—24	2
12—25	2
12—26	2 (a pair)
13—24	2
13—25	7 (incl. 1 pair)
13—26	11 (incl. 3 pairs)
13—27	5
14—24	1
14—25	4
14—26	1
14—27	2

GROWTH CHARACTERS: There are a few consistent age differences apparent in the series under consideration: In the smaller specimens, the dorsal and anal lobes are relatively lower, the stomach is slightly shorter, the liver has not as many small, sub-lobes and the reproductive organs are poorly developed.

ECOLOGY.

SIZE AND WEIGHT: Reports of Portland tuna smaller than 33 pounds can not be verified, and even these relatively small fishes are exceedingly rare. It is probable, however, that much smaller tuna are sometimes taken in the mackerel nets; John Doughty, an experienced tuna fisherman, took a two and one-half pound fish from one of these nets last year, which he is certain was a true tuna; he states that the shape of the fish, the appearance of the fins and the color and arrangement of the finlets all were typical of a tuna.

The largest tuna harpooned are supposed to have reached 1,600 pounds, but these weights are unofficial, having been taken from a newspaper report. Recorded weights for Portland fish reach 967 pounds. The majority weigh between 300 and 700 pounds.

When the tuna appear off Portland in the early summer (see below), they are always much thinner than later on. However, large fish which are caught on the same day in mid-summer and which are equal in length, may differ almost a hundred pounds in weight (see measurement table, p. 209); in the case observed, at least, sex was not a factor, as both of the largest specimens listed were spent males.

SEX: Every one of the 30 specimens examined was a male. Of these, five of the largest (weighing 700 pounds and over) had broadly distended sperm ducts and spent testicles. In all of the others the testicles were far from being in breeding condition, while the sperm ducts were extremely slender.

OCCURRENCE: Every year the first tuna appear in the latter part of June, are common in July and August, and become scarce in September. They vanish altogether early in October. Their season corresponds exactly to that of the herring and mackerel. Usually the tuna remain outside of Casco Bay in at least 35 or 40 fathoms of water and 12 or more miles from the dock. This year, however, they have occasionally been seen further inshore. There is no report of the occurrence of any other species of tuna in this area.

SCHOOLING: Fish of approximately the same size form small schools of which up to twenty or more may be visible at the surface at once, leaping or swimming slowly along with the tips of their fins breaking water. Small and large fish are never seen in the same school. As a rule, the smaller

the fish, the more individuals in the school, while the largest fish often seem to be solitary.

PARASITES: The 860-pound specimen mentioned earlier in the paper had many dark red *Caligus* sp. on the bases of the anal fin, of the dorsal and anal finlets and of the caudal fin. A few were found on the finlets and the caudal fin. There were *Distoma*-like worms in about half a dozen of the 34 stomachs examined.

FOOD: The following food was present in the 34 stomachs examined:

Food	Nos. of stomachs in which it occurred
Merluccius bilinearis (from 1 to 38 fish in a single stomach, each measuring from 8 to 13 inches in length. In most of the tunas the food consisted entirely of this species)	26
Seaweed (in stomachs containing little other food; only one or two fronds were found in each stomach)	4
Squids (one or two in a stomach, alone or with shrimps)	3
Meganyctiphanes norvegica (numerous; all adults)	2
Clupeid, 215 mm.	1
Clupeids, different from above; three, ca. 75 mm.	1
Sebastes marinus; four, 53 to 117 mm.	1
Tylosaurus marinus; one, 135 mm.	1

Five of the tuna stomachs were completely empty. Almost all of the food was in an advanced state of digestion.

Previous records of the food of Maine tunas are few and indefinite. Bigelow ("Fishes of the Gulf of Maine," 1925, p. 213) states that the principal food consists of menhaden, mackerel and herring, with occasional dogfish, squid and the smaller schooling fishes. Rich (*loc. cit.*) also writes that herring, mackerel and menhaden are the most important elements of diet. The fishermen almost never open the stomachs, except by accident, and know only that tunas "often eat herring and mackerel." Since four genera of "herring" and five of "mackerel" occur in the Gulf of Maine, and since my few days' work yielded five kinds of organisms previously unrecorded as tuna food, the need for detailed and sustained work on this interesting subject is evident.

EXPLANATION OF THE PLATE.

PLATE I.

Fig. 1. A typical tuna-fishing boat of Portland, Maine, showing bow platform. Photograph from Walter H. Rich.

Fig. 2. A fisherman in position for a strike. Photograph from Walter H. Rich.

Fig. 3. An 860-lb. specimen of *Thunnus thynnus* taken off Portland in July, 1936. Photograph by Dr. J. S. Jamieson.

FIG. 1.

FIG. 2.
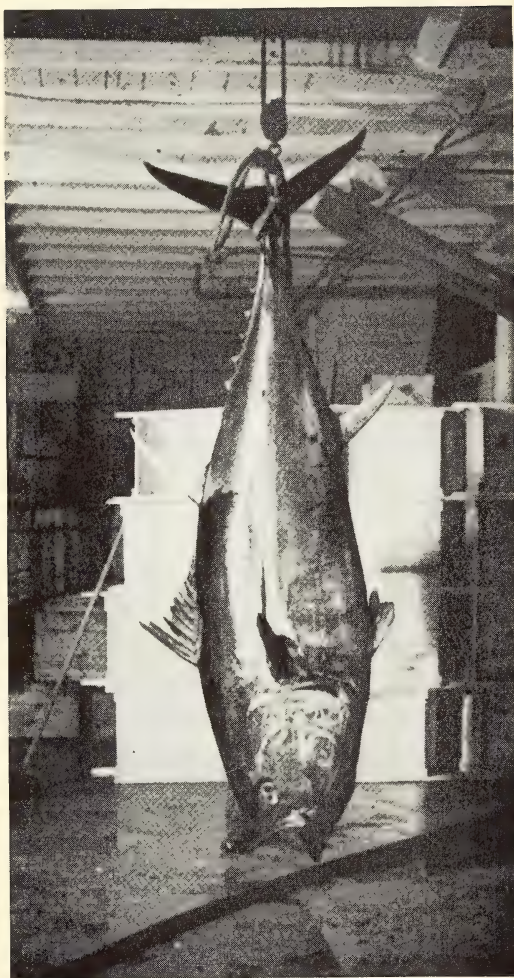
FIG. 3.

NOTES ON THE BIOLOGY AND ECOLOGY OF GIANT TUNA, THUNNUS
THYNNUS LINNAEUS, OBSERVED AT PORTLAND, MAINE.

17.

The Templeton Crocker Expedition. I. Six New Brachyuran Crabs from the Gulf of California[1].

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[Introductory Note: This is the first of a series of papers dealing with the specimens collected on the Twenty-fourth or Templeton Crocker Expedition of the Department of Tropical Research of the New York Zoological Society; William Beebe, Director.]

MAJIDAE.

Mithrax (Mithrax) mexicanus Glassell, sp. nov.

Type: Male, holotype; Cat. No. 36,712, Department of Tropical Research of the New York Zoological Society; Station 136, Dredge 27; from the Gulf of California, 23° 28' N. Lat., 109° 24' W. Long., 3 miles northeast of Cape Pulmo, Lower California, Mexico; 50 fathoms; April 30, 1936; 4-foot Blake dredge; collected by William Beebe on Templeton Crocker's yacht *Zaca.*

Diagnosis: Horns long, divergent. Antennae long. Hepatic spine single, most prominent of lateral spines. No paired spinules on mesogastric region.

Description of male: Carapace pyriform, tumid, setose, much longer than wide; lateral margins without an angle. There are six median spines, none very prominent, except the posterior marginal spine. Of the five antero-lateral spines the hepatic is the most prominent, the other four being small; a subhepatic spinule; a prominent postero-lateral spine, about half the size of the hepatic spine, located above the level of the antero-lateral spines; a pair of epibranchial spines paralled the antero-lateral spines; a pair of spines on the metabranchial region parallel the antero-lateral margin. The rostral horns are nearly ¼ the body length, diverging, regularly tapering. The suborbital margin is armed with two spines, the median large, the distal largest and prominent in dorsal view; the supraorbital margin has three spines, postorbital, preorbital and median, the latter the smallest. The antennae are nearly as long as the width of the carapace.

Chelipeds small, not as long as the first ambulatory leg; merus with a spine at upper distal end, another just proximal to this; carpus with 3 or 4 small dull spines; hands smooth, cylindrical; fingers not gaping.

First ambulatory leg nearly as long as the carapace; legs tomentose and setose; merus armed with a distal spine on upper carpal articulation. Terminal segment of abdomen longer than wide, sides converging, tip arcuate; not as wide as penultimate segment. Buccal area widest anteriorly.

Measurements: Male holotype, length of carapace including rostral horns 16.2 mm., width 9.4 mm.

Material examined: The male holotype.

Remarks: This proposed species is closely allied to *M. (M). spinipes* (Bell), 1835 (1836), but differs from that species in that it lacks the small, side by side spinules on the anterior mesogastric region; by the carapace being pyriform, instead of having a lateral angle, in this respect it also differs from *M. (M). acuticornis* Stimpson, 1870. It differs from both of these species in that the hepatic spine is the most prominent, the others being very small, and by the shape of the ultimate segment of the abdomen being subquadrilateral, instead of subtriangular.

Stenocionops beebei Glassell, sp. nov.

Type: Female, holotype; Cat. No. 36,714, Department of Tropical Research of the New York Zoological Society; Station 136, Dredge 23; from the Gulf of California, 23° 28' N. Lat., 109° 24' W. Long., 1½ miles northeast of Cape Pulmo, Lower California, Mexico; 50 fathoms; May 1, 1936; 4-foot Blake dredge; collected by William Beebe on Templeton Crocker's yacht *Zaca*.

Diagnosis: Median spines 5; none on posterior margin. Lateral marginal spines 3. Rostral horns widely divergent, about 78°, nearly 1/5 length of carapace.

Description: Carapace triangular-ovate; regions tumid, covered with thick sponge-like pubescence and groups of curve-tipped setae. Median spines 5, the anterior very small, the rest large, stout, cylindrical, blunt; three large, conical, upward-pointing, lateral spines, the hepatic joined to the smaller subhepatic by a ridge; a pair of stout upward-pointing, mesobranchial spines, one of which is opposite the cardiac region; with the proximal antero-lateral spines and the cardiac spine, these form a transverse line of five heavy spines across the carapace at this point; the other branchial spines with the median lateral spines form a transverse row of four spines across the carapace at the metagastric region.

Rostral horns widely diverging, at an angle of nearly 78°, regularly tapering to slender, slightly incurving tips. Supraorbital spine heavy, upturned; preorbital spine separated from supraorbital by a long narrow sinus.

Chelipeds almost as long as first ambulatory leg; merus armed on upper crest with 4 large spines and a distal lobe; carpus roughened with a few low tubercules; manus long, cylindrical, tapering, armed with a single proximally placed tubercule on upper margin; fingers long, tapering, slightly gaping proximally. Ambulatory legs stout, pubescent; dactyli pubescent, curved.

Color in alcohol: Spines a bright pink. Fingers brown, tips white.

Measurements: Female holotype; length of carapace with horns 56 mm., without horns 48 mm., length of rostral horns 10 mm., width of carapace with lateral spines 45 mm., without spines 38 mm., length of hand including fingers 24 mm., width at base 4 mm.

Material examined: The female holotype, and a juvenile male paratype from the same dredge haul.

Remarks: This proposed species is allied to *S. triangulata* Rathbun, 1892, but differs from that species, not only by being larger, but, by having 5 median spines, instead of 9, and by having 3 large, lateral spines, instead of 3 lateral spines and a hepatic.

This species is named for Dr. William Beebe, director of the Department of Tropical Research of the New York Zoological Society, whose ex-

ploits and adventures in the field of natural history have cast a glamour on his calling, and honor on his fraternity.

XANTHIDAE.

Actaea crockeri Glassell, sp. nov.

Type: Male, holotype; Cat. No. 36,731, Department of Tropical Research of the New York Zoological Society; Station 136, Dredge 5; from the Gulf of California, 23° 31' N. Lat., 109°.27' 30" W. Long., 2 miles south-southeast of Punta Arena, Lower California, Mexico; 33 fathoms; April 19, 1936; 4-foot Blake dredge; collected by William Beebe on Templeton Crocker's yacht *Zaca*.

Diagnosis: Carapace with regional lobes spinuous anteriorly; tuberculate posteriorly; lateral lobes dentiform. Ambulatory legs crested with a double row of lanceolate teeth on carpus and propodus. Chelipeds covered with thickset forward-pointing spinules, coarser than on carapace.

Description: Carapace ovoid, nodulous; deeply furrowed, nude; the nodules on the anterior half thickly covered with short, sharp-tipped, forward-pointing spinules; those of the posterior half, less thickly covered with tubercules and granules. A granular ridge parallels the posterior border. Cardiac region divided by a median sulcus. Front deflexed, a small median sulcus, lobes arched, spinuous in dorsal view, sinuous in front view. Upper ocular margin serrate with short, sharp-pointed spines; lower margin tuberculate. Lateral dentate lobes four (besides the orbital), the first very small, the second smaller than the third and fourth; second and third, forward and upward pointing, granulate on posterior face, spinate anteriorly; the margins of 1—2—3 teeth are serrate with forward-pointing spinules.

Chelipeds unequal, the right the larger, covered with short, sharp granules; the carpus with a distal transverse sulcus paralleling the margin, a spine at the inner angle; hands covered with thickset sharp spinules; fingers channeled, that of the major hand crested. Ambulatory legs short; merus with a row of short spines on upper margin, granulous; carpus and propodus armed with an irregular double row of lanceolate spines on the flattened, channeled surface, also with spines and granules on the posterior side; dactyli pubescent. Merus of outer maxillipeds with truncate, cylindrical tubercules.

Measurements: Male holotype, length of carapace 5.5 mm., width 8 mm.

Material examined: The male holotype.

Remarks: This proposed species is allied to *A. angusta* Rathbun, 1898, but differs from that species by having the posterior half of the areolate carapace granulate, the anterior areolations spinuous, instead of all the areolations granulous, by having the lateral lobes covered with spinules, instead of granulous, and by the legs being heavily spined, instead of granulous.

This species is named for Mr. Templeton Crocker whose interest and generosity made possible this expedition.

Pilumnus pelagius Glassell, sp. nov.

Type: Female, holotype; Cat. No. 36,731, Department of Tropical Research of the New York Zoological Society; Station 136, Dredge 13; from the Gulf of California, 23° 29' N. Lat., 109° 24' W. Long., 5½ miles southeast of Punta Arena, Lower California, Mexico; 45 fathoms; April 20, 1936; 4-foot Blake dredge; collected by William Beebe on Templeton Crocker's yacht *Zaca*.

Diagnosis: Antero-lateral spines 4, forming a ridge which leads downward to buccal angle. Carapace covered with pubescence forming a ragged pattern. Upper surface of carpus and manus of chelipeds flattened; outer surface of hands rough and pubescent.

Description: Carapace about 2/3 as long as wide, uneven, lumpy, and rough with scattered tubercules and granules amid the pubescence. Regions margined by deep wide furrows, a deep median sulcus. Front deflexed, bilobed, the outer margin of each lobe slightly concave. A spine at outer angle of orbit, followed below by two spinules and a row of long hairs. Antero-lateral spines forming a downward curve toward the buccal cavity but joined at their bases in a smooth carina leading to the orbit; the two posterior spines are much nearer than the remainder, and surmounted at their apices with fine, sharp, forward-pointing spinules. A few spinules on subhepatic region.

Chelipeds, except the fingers, densely pubescent, setaceous, concealing the sharp granules or spinules interspersed; a stout, heavy, sharp-tipped spine at inner angle of carpus; upper surface of carpus and manus flattened; manus with a line of 5 or 6 spinules on flattened upper surface; fingers nude, except for proximal upper crest of dactyli; dactyl of major hand armed with heavy, lobe-like teeth, the one at the gape the heaviest.

Ambulatory legs of moderate length, pubescent, and furnished with a fringe of longer hairs, concealing spinules on upper surface. Abdomen covered with pubescence and fringed with long hairs.

Sexual variation: None.

Color in alcohol: Anteriorly rather pink. Spines on ambulatory legs a rose color. Fingers a dark brown. Pubescence a dirty brown.

Measurements: Female holotype, length of carapace 9 mm., width 14.3 mm. Male paratype, length 7.2 mm., width 9.2 mm.

Material examined: Two females and one male including the type; all three specimens were taken in the same dredge haul.

Remarks: This proposed species is allied to *P. limosus* Smith, 1869. but differs from that species in that the anterior half of the carapace is not so densely tomentose, the antero-lateral spines are not in one plane, the front without a deep, wide, median sulcus, the ambulatory legs with spines and setae. The abdomen of the male is relatively wider, with the ultimate segment subtruncate, instead of triangular as in *P. limosus.*

GONEPLACIDAE.

Chasmocarcinus ferrugineus Glassell, sp. nov.

Type: Female, holotype; Cat. No. 36,735, Department of Tropical Research of the New York Zoological Society; Station 136, Dredge 21; from the Gulf of California, 23° 29′ N. Lat., 109° 25′ W. Long., 5 miles southeast of Punta Arena, Lower California, Mexico; 45 fathoms; April 30, 1936; 4-foot Blake dredge; collected by William Beebe on Templeton Crocker's yacht *Zaca.*

Diagnosis: Orbits transverse. An antero-lateral marginal granulate line. Sternum and abdomen of female lightly pubescent and punctate; abdomen heavily fringed. Merus of ambulatory legs wide.

Description: Carapace nearly ¾ as long as wide. Fronto-orbital distance less than one-half the width of carapace. Surface covered with pubescence, punctate, granular toward the marginal angle and the posterior border; sparse, clavate setae on the sides, antero-lateral shoulders and the eye-stalks. Two deep longitudinal impressed lines in the center of the carapace. A distinct, blunt, granular antero-lateral margin. Front trun-

cate, straight, entire. Eyes filling the orbits; orbits transverse in dorsal view. Second and third joints of antennules very long.

Chelipeds lightly margined with hair, for the most part smooth; merus with a transverse rounded lobe near distal end, a double margin parallels the carpal articulation; ridges and lobes setose; carpus nearly square with a setose lobe at inner angle; hands with fingers long, regularly tapering, slightly arched, crossing at the tips, not gaping; pollex subhorizontal; lower margin of hand slightly sinuous, with granulate, setose margin.

Ambulatory legs long, hairy; merus stout. Female abdomen lightly pubescent and punctate, with heavy marginal fringe.

Color in alcohol: Pubescence and setae a dull brick red or rusty color. Carapace under pubescence a bluish-gray.

Measurements: Female holotype, length of carapace 9.2 mm., width 13 mm. Male paratype, length 7.5 mm., width 10.5 mm.

Material examined: Two females, one male, including the holotype; all three specimens from the same dredge haul.

Remarks: This proposed species is closely allied to *C. latipes* Rathbun, 1898, but differs from that species in that the orbits are transverse, instead of oblique, the eyes fitting the orbits, instead of not fitting, the merus of the chelipeds with an upper subdistal, transverse lobe or prominence, instead of without this lobe.

It may be that this species is analogous to *C. latipes.* To establish these differences with absolute certainty, however, the examination of a number of specimens is necessary.

CYMOPOLIIDAE.

Cymopolia zacae Glassell, sp. nov.

Type: Male, holotype; Cat. No. 36,739, Department of Tropical Research of the New York Zoological Society; Station 136, Dredge 26, from the Gulf of California, 23° 27' N. Lat., 109° 24' W. Long., 2 miles northeast of Cape Pulmo, Lower California, Mexico; 45 fathoms; May 1, 1936; 4-foot Blake dredge; collected by William Beebe on Templeton Crocker's yacht *Zaca.*

Diagnosis: Five unequal antero-lateral teeth. Carapace half again as wide as long. First ambulatory leg reaching nearly to distal end of carpus of second.

Description: Carapace very broad and not very convex, with five antero-lateral teeth besides orbital tooth; the first two triangular, sub-acute, having a longer base than the third and fourth; these four teeth are upturned and forward-pointing; the fifth tooth is lamellar, horizontal, on a lower plane and occupies the lateral angle. Tubercules of carapace well marked, high, trending forward; intervening space filled with inconspicuous granules and scant, short hairs. Two median frontal teeth rounded and separated by a triangular sinus with a sharp base; lateral sinuses shallow, wider, oblique; lateral teeth rounded, lobular. The first sinus of supraorbital margin is narrow U-shaped; the second V-shaped; middle tooth broad, obliquely truncate, next tooth narrower, rounded. Outer orbital tooth inclined forward and inward, outer margin straight. Ridge above posterior margin crenulate with small tubercules.

Chelipeds slender, subequal, the right the major; fingers with tips crossing. Sinuses of suborbital margin V-shaped, the inner the sharpest; outer lobe oblique, bilobed; inner lobe truncate, rounded posteriorly, advanced to half the height of outer lobe and spatulate pterygostomian lobe.

First ambulatory leg slender, reaching nearly to distal end of carpus of second; dactyl slightly curved; second and third legs nearly twice as long as width of carapace; merus joints narrowing in distal half; four longitudinal crests, anterior distal end forming a right angle; anterior lobes on carpus obsolete, the margin forming a straight crest, the distal end concave with a small tooth on propodal articulation; propodus enlarging little distally; dactylus with sinuous posterior margin.

Measurements: Male holotype, length of carapace 8.5 mm., width 13.1 mm., length of second leg 25.5 mm., length of first leg 11.8 mm.

Material examined: The male holotype.

Remarks: This proposed species is closely allied to *C. fragilis* Rathbun, 1893, but differs from this species in having five antero-lateral spines, instead of four, by having the first leg extending past the merus of the second, instead of not extending past the merus, by the suborbital lobe being truncate, instead of bilobed, and not equally advanced with the pterygostomian lobe.

This species is named for Mr. Templeton Crocker's yacht *Zaca* of San Francisco, California, on board of which members of the New York Zoological Society made an expedition into the Gulf of California during 1936 and collected the specimens described in the present paper.

18.

Neoplastic Diseases in Small Tropical Fishes[1].

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C. W. COATES,
New York Aquarium,
&
L. C. STRONG,
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(Plates I-III).

Although many thousands of the smaller tropical fishes have been under observation at the New York Aquarium during the past five years, representing approximately 400 species, it is of interest to note that in only five species has a tendency toward neoplasia been observed to date. These species were the following:

1. Hybrids of the Mexican killifish, *Xiphophorus helleri* Heckel and *Platypoecilus maculatus* Guenther.
2. *Rasbora lateristriata* (Bleeker).
3. *Rasbora trilineata* Steindacher.
4. *Rasbora daniconius* (Hamilton-Buchanan).
5. *Heterandria formosa* Agassiz.

Before 1875 tumors in fishes were practically unknown. It was believed by many early pathologists that tumors were a characteristic of man and the warm blooded animals in general, and that such new growths did not occur in cold blooded creatures. It was Bugnion (1875) who is usually credited with the earliest precise description of a fish tumor. This growth was a giant cell sarcoma and occurred in the small European fish called the Ellritze—*Phoxinus laevis*. With the end of the last century and the beginning of the new, greater interest manifested itself in the study of tumors in fishes, due largely to the widespread effort to learn about the origin of cancer. As the result of the careful studies of Plehn (1906), Johnstone (1915), Takahashi (1929), Thomas (1931), Haddow and Blake (1933) and other investigators, various types of tumors in many species of fishes were described. But even today our knowledge of fish tumors remains very incomplete. There is little information regarding pathogenesis and course of these hyperplastic lesions. We have no idea about the factors which, on the one hand favor the growth of these tumors and, on the other, inhibit their progress. One difficulty has been that relatively few tumors come under observation, as it is well known that fishes succumb rapidly to any form of disease and sick fishes are attacked and destroyed by other fishes.

Some peculiarities of fish tumors are now recognized. For example,

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they remain very much localized and seem to be less infiltrative and destructive than mammalian and avian tumors. Transplantation of tumor tissue from fish to fish, though frequently attempted, has been uniformly unsuccessful, even when this has been undertaken with great care and exacting technique. The occurrence of secondary growths or metatases, so frequently seen in mammals and in birds, is rarely encountered in the case of fishes. This has been thought to be due to the fact that the lymphatic system of the fish is merely a diffuse arrangement of capillaries and spaces possessing no organized lymphatic glands (Haddow and Blake, 1933). Secondary tumors in fishes seem to be the exception even with such growths as the black pigmented melanoma, which in the human being is most malignant and causes many widely scattered secondary growths followed by rapid death. Owing to the numerous cutaneous pigment cells, containing granules of different colors (black, red, yellow, etc.), the skin of fishes has proved unique for the study of pigmented skin tumors. Some of these show a marked difference from the skin tumors arising in terrestrial animals. Thus, beside the commoner grayish-white fibromas of the skin, there are known to be greenish-yellow tumors of the skin, red tumors or erythrophoromas, black tumors or melanomas, and even a silvery irridescent tumor composed of cells containing irridescent crystals. The last tumor has been described by the Japanese investigator Takahashi (1929), and he has named this a guanophoroma. All these colored cutaneous tumors in fishes are highly prized at the present time, because some of them occur in the extensively inbred small tropical fishes. They are furnishing an accurate means of studying certain genetic principles underlying the causes of tumor growth and cancer.

A neoplastic disease designated by Reed and Gordon (1931) as "Melanotic Over-growth," is shown in Plate I, Fig. 1. It occurs in the hybrids of the small Mexican killifish. Several instances of this condition have come under our own observation. The disease has been studied extensively from the genetic standpoint by the European investigators Haüssler (1928) and Kosswig (1929) as well as by the Americans Reed and Gordon (1931). The condition is characterized by a great multiplication of the black pigment cells or melanophores which normally lie in small collections in the derma directly under the transparent epidermis. With massing of these newly formed melanophores, the affected part of the skin turns an intense black. Very large collections of melanophores may actually form tumors which penetrate into deeper lying muscles and destroy adjacent tissues. Thus, in the later stages of the disease, the tail and the tissues at the base of the tail may become invaded, destroyed and lost by a process of sloughing. (Pl. I, Fig. 2).

In another of the hybrids of *Platypoecilus maculatus* and *Xiphophorus helleri*, which is highly pigmented in red, there arose a brick red tumor in the region of the dorsal fin. (Pl. I, Fig. 3). This small mass had its origin in a field of red pigmented cells (erythrophores) seen as an irregular red patch in the mid dorsal region. The tumor invaded the skin and the tissues of the dorsal fin, but not the deeper lying muscles. Histologically, the cells composing the tumor are rather large, round, oval, or somewhat fusiform (Pl. II, Fig. 5). They show at times small protruding branches or dendrites. The nucleus of the cell is small, and usually centrally located. The body of the cells, prepared by the method of frozen sections, contained minute granules of a dark red or orange color. These granules assumed a bright red stain in the presence of Scharlach R., and were regarded as lipoidal in character. In sections prepared by the paraffin method, the pigment granules become dissolved, and the cytoplasm of the cells appear shrunken and vacuolated. The red or orange pigment granules give the characteristic red tint to the tumor during life. No black pigmented cells were noted in any of the sections examined. The supporting tissue of the tumor cells

are very delicate connective tissue cells which support a fine network of small capillaries. Nerves were not noted. The overlying epithelium of the skin consists of several layers of cells, but without any appreciable thickening.

Erythrophoromas in fishes are distinctly rare. Thomas (1931) of France described three such tumors in relatively large fishes. One occurred in a tunny fish, and the other two were in the trout. More recently a metastasizing cutaneous erythrophoroma was noted in a winter flounder caught in the waters of Long Island Sound (Smith, 1934). Two instances of erythrophoroma were produced experimentally by Kosswig (1929) by cross breedings between *Platypoecilus maculatus* and *Xiphophorus helleri*.

DISCUSSION ON THE GENETICS OF FISH TUMORS.
(L. C. STRONG).

Susceptibility to spontaneous tumor formation has been very completely demonstrated, on a genetic basis, by Reed and Gordon (1931) in hybrids of the Mexican killifish. They showed, in the first place, that the production of macromelanophores (the histological unit involved in the formation of the larger black areas of the fish) is inherited as a sex-linked dominant factor; secondly, that another factor, an intensifier, found in *Xiphophorus helleri*, is also inherited as a dominant; thirdly, that both factors in their original location manifest themselves in an orderly manner; lastly, that if both determiners are introduced into a hybrid fish, "macromelanophore invasion results in a state of general melanosis in which there is a deterioration and final complete replacement of normal tissues by the invading cells. A state is reached where there occur sharply delineated overgrowths, the final tissue of the affected part is clearly a neoplasm." Thus it was determined that hybridization, used for the production of new varieties by recombinations of variations in diverse species, had actually given a combination of genetic determiners that led invariably to tumor formation. The very important question arises whether these same factors in the original species, not influenced by other determiners from other species, could, by themselves, produce an abnormal growth such as a tumor. The problem presents itself to a geneticist, "Has something gone wrong with the genetic factor or factors which control the presence and physiological activity of the erythrophore (red pigmented cell) in this fish where an erythrophoroma was produced?" The question is an important one not only from the standpoint of the fish fancier but also to the student of neoplasms in general. The problem needs further investigation. It could be worked out just as completely as Reed and Gordon have done with the black tumors by the following procedure: 1. The histological examination of fishes with red tumors received by a pathologist when the fishes are still alive, and (2) the statistical analysis of the descendants of a fish known to have a red tumor at some time during its life. It is hoped that fish fanciers may become interested in the presence of tumors in their stocks and that they will make available to other investigators such material as may come to their attention.

Contrasting with these neoplasms in hybrids of the Mexican killifish above discussed was a small solitary fibrous growth seen in *Rasbora daniconius* (Hamilton-Buchanan), (Pl. I, Fig. 4). This was a spontaneous tumor in the region of the dorsal fin, sharply circumscribed, black in color externally where the melanophores of the derma have aided in forming a capsule around it. On sectioning the tumor, however, it was noticed that the black color was strictly limited to the periphery of the growth, and that the interior was composed of firm white fibrous tissue. Microscopically

the tumor is composed of loosely arranged interlacing bundles of elongated connective tissue cells, in places hyaline in character (Pl. II, Fig. 6). The blood vessels are very few in number. The tumor appeared to belong to the group of fibromas and was regarded as benign in nature. Melanophores were irregularly scattered over the surface of the tumor, and the overlying epidermis was destroyed. The melanophores were doubtless corial in their origin and did not constitute a part of the tumor as such.

Epithelial and glandular tumors in this small series of neoplasms were represented by two hyperplastic growths of the thyroid gland, the first occurring in *Rasbora lateristriata* (Pl. III, Fig. 9) and the second in *Heterandria formosa* Agassiz, (Pl. III, Fig. 10). Microscopically, these tumors resemble each other fairly closely in that they are composed of masses of thyroid tissue, partly in a dense compact arrangement of cells without acini or follicles, partly in closely grouped follicles distended with varying amounts of colloid material (Pl. II, Fig. 7). Both tumors in the extension of their growth have encroached upon the structures of the gills, so that the thyroid tissue replacing in part the epithelium of the gills lies in closest contact with bone, cartilage, and muscle tissue. There is no tendency to form a capsule.

To what extent the invasion of the gill structures can be regarded as an evidence of malignancy in the case of thyroid tumors in fishes, is still a matter of individual interpretation. It is not unlikely, however, that such an extension beyond normal topographical limits on the part of a massed growth of thyroid tissue encroaching upon bone, cartilage, muscle and epithelium, may actually represent neoplasia of the thyroid gland of a varying degree of malignancy. In both our fishes, the growth regarded as adenocarcinoma, was a spontaneous one, forming an appreciable sized tumor without metastases. Other fishes in these same tanks were not affected in any way, strengthening the belief that the disease was not infectious. Similar tumors occurring in other fishes, notably in the trout, have been designated as adenocarcinoma. Widely studied in Europe and in this country by Gaylord and Marsh (1914), Marine and Lehnhart (1910), the disease has been attributed to an unknown agent in the water, perhaps of an infectious nature, causing a disturbance in nutrition or metabolism. The disease has not been transmitted by transplanting the diseased thyroid tissue into other fishes of the same order.

The last tumor of the present series of tumors in small tropical fishes occurred in *Rasbora lateristriata* (Bleeker). This fish developed a swelling in the upper abdominal region near the liver. The intra-abdominal swelling could be seen distinctly during life through the semitransparent abdominal wall of the fish. After approximately two months of observation, the swelling extended cephalically, and presently it was noticed that the right operculum was pressed outward by a mass of whitish tissue involving the gill on the right side (Pl. III, Fig. 11). The health of the fish became impaired and it was then sacrificed for the purpose of histological study. Serial microscopic sections were prepared of the entire head and the abdomen.

The tumor tissue is composed of closely packed small lymphoid cells, with deeply staining nuclei and scant cytoplasm. There are many small necrotic areas where the determination of the structure of the tissue is difficult. Here and there, intermingling with the masses of small lymphoid cells, are larger paler vacuolated cells with vesicular nuclei, which suggest structurally a larger type of lymphoid cell or a degenerating form of lymphoid cell. The exact site of origin of the tumor cannot be determined by the microscopic study of the sections. The principal mass lies in the abdomen ventral to the liver, spleen, kidney, gastro-intestinal tract and ovarian tissue, yet in closest relation with all these organs. Plate II, Fig. 8

shows the tumor close to a part of the stomach. There is a distinct fusion between tumor and the ventral peritoneum at one point, suggesting that the neoplasm had its beginning in lymphatic tissue near the peritoneum. The tumor was regarded as a lymphosarcoma with invasive malignant properties.   It extended as an irregular mass from the abdomen in a cephalic direction, passing to the right of the heart to the roof of the oral cavity, reaching outward and to the right to involve and destroy in large part the tissues of the gill.   There was also an extension of the tumor into the cranial cavity, where it reached as far as the base of the brain and laterally to the lower boundaries of the right and left saccule of the auditory apparatus.   The tumor encroached upon muscle, bone, and cartilage wherever these structures were encountered in its course, causing in places their destruction.

We found no parasites in tumor tissue, although several small encysted parasitic larvae were noted in the abdomen at points remote from the growth.   The examination of the blood found in cross sections of the heart and the larger blood vessels indicated no increase in the white cells, such as might be expected in a leukaemic state if this were present.

SUMMARY.

In this paper several neoplastic diseases are described occurring in certain species of the small tropical fishes.   These are (1) "Melanotic Over-growths" and a red pigmented tumor (erythrophoroma) in hybrids of *Xiphophorus helleri* Heckel and *Platypoecilus maculatus* Guenther;   (2) Fibroma in *Rasbora daniconius* (Hamilton-Buchanan) ; (3) Adenocarcinoma of the thyroid in *Rasbora trilineata* Steindacher and *Heterandria formosa* Agassiz; (4) an extensive lymphosarcoma in *Rasbora lateristriata* (Bleeker). The first group of pigmented cutaneous tumors in the hybrids of the Mexican killifish are discussed from the genetic viewpoint.

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EXPLANATION OF THE PLATES.

PLATE I.

Figs. 1 and 2. Melanotic overgrowth occurring in hybrids of the Mexican killifish. Fig. 1 shows a moderately severe black pigmentation of parts of the skin, while Fig. 2 shows an advanced lesion with a tumor-like mass near the base of the tail which has been almost completely destroyed with the progress of the disease.

Fig. 3. A red pigmented tumor (erythrophoroma) growing in a hybrid of the Mexican killifish *Platypoecilus maculatus* and *Xiphophorus helleri*. The growth involves the region of the dorsal fin. Drawing made from living fish.

Fig. 4. *Rasbora daniconius*, with a small fibroma growing on the back of the fish near the dorsal fin. The fibroma is surrounded with a capsule containing black pigment cells. Drawing made after death of the fish.

PLATE II.

Fig. 5. Photomicrograph of erythrophoroma occurring in fish represented in Plate I, Fig. 3. Large, round, oval or fusiform cells with relatively small nucleus. These cells in the fresh condition contained granules of red or orange pigment, which gave the red tint to the tumor. x 230.

Fig. 6. Photomicrograph of tumor occurring in *Rasbora daniconius*, depicted in Plate I, Fig. 4. The tumor is composed of interlacing bundles of elongated connective tissue cells. A moderate number of black pigmented cells, called melanophores M, are shown in the periphery of the growth. x 80.

Fig. 7. Photomicrograph of thyroid tumor occurring in fish depicted in the photograph Fig. 9. A, compact thyroid growth; B, an area of the growth showing thyroid tissue arranged in follicles; C, thyroid tissue infiltrating the structure of the gills, G. x 85.

Fig. 8. Photomicrograph of lymphosarcoma X in relation to area of the stomach, S. x 200.

PLATE III.

Fig. 9. *Rasbora lateristriata* showing neoplasm of the thyroid.

Fig. 10. *Heterandria formosa* with neoplasm of the thyroid.

Fig. 11. Photograph of the ventral side, *Rasbora lateristriata*. A, indicates mass occupying the abdomen, and B, the extension of the growth to the gill of the right side.

PLATE I.
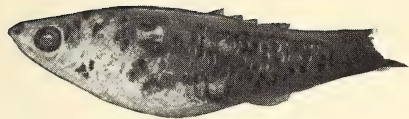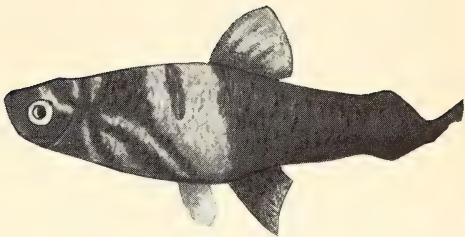
FIG. 1.

FIG. 2.
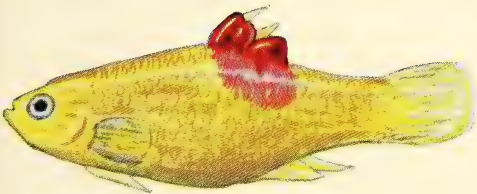
FIG. 3.
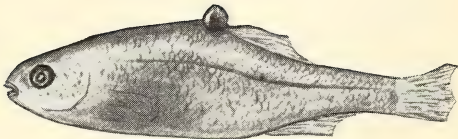
FIG. 4.

NEOPLASTIC DISEASES IN SMALL TROPICAL FISHES.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

NEOPLASTIC DISEASES IN SMALL TROPICAL FISHES.

PLATE III.

FIG. 9.

FIG. 10.

FIG. 11.

NEOPLASTIC DISEASES IN SMALL TROPICAL FISHES.

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS

OF THE

NEW YORK ZOOLOGICAL SOCIETY

CONTENTS

19.

The Southwestern Desert Tortoise, *Gopherus agassizii.*

CHAPMAN GRANT.

Several enterprising youths in the vicinity of Hodge, San Bernardino County, California, have started commercializing the desert tortoise, *Gopherus agassizii.* May 8-11, 1935, was spent examining several small collections and Robert Heckly's two hundred specimens which were for sale to tourists. On another trip, October 2-9 inclusive, one hundred more specimens were examined. Most were in captivity, some were captured and some shells of dead specimens were studied. The favorable hours during which the tortoise ventures abroad were devoted to field work. Some observations that have not been seen in print are offered, together with additional data which may prove of interest.

ASYMMETRY.

Examination of plastrons showed that the suture between gulars is offset to the right from one to five millimeters, making the left gular wider. It does not protrude farther, but has a wider base and grows farther back on the plastron. Among 366 specimens, 331, or 90%, had the suture on the right, 23, or 6%, were median and 11 females and 1 male, or 3%, had a left suture. The 23 with central sutures were about evenly divided between the sexes. Plate XXIV of Ditmars' "The Reptile Book" (1907) illustrates the asymmetry. Additional evidence is shown in 15 plates by O. P. Hay in "The Fossil Turtles of North America." The left gular is larger in 7 plates and in no case is the right larger. Asymmetry of the gular scutes is in contrast to the median suture of the symmetrical underlying epiplastral bones. The gulars are either forked or worn chisel-shaped and recurved to a varying degree without apparent reference to age.

DIMORPHISM.

In the males secondary sexual dimorphism consists of larger size, longer gulars and tail, smaller pelvic clearance measured from seam of anals to edge of rear marginals, thickened anals and concave plastron, characters which make their appearance as the juveniles exceed 12 or 14 cm., with the difference in tail length showing first. The sexes have similar proportions except that the male exceeds by 2% in length of gulars and 5% in tail length, with a 2% smaller pelvic clearance. Among 366 specimens 19 females, 7 males and 4 young had major scute atavisms or abnormalities. One female was nearly circular, having narrow costals; another was elongated, having extra scutes, and a third was exceptionally high. The young are light, but color apparently has no sexual significance. Two partial albinos were seen with carapace, legs and toenails olive gray. The legs of

one large male were orange and black instead of the usual gray and black. Varying recurvature of the marginals over the hind legs and the amount of curving-under of the pygal as well as the considerable variation in number and arrangement of the inguinals are without apparent sexual significance. The color of the iris is brassy or brown or these two colors mottled, with about 80% brassy, 10% mottled and 10% brown without correlation to sex or age.

DIMENSIONS.

Table of dimensions in cm.

	30 adult females	Largest female	30 adult males	Largest male
Carapace length....	24.27	28.6	28.3	33.7
Carapace depth....	10.4	11.5	12.	14.6
Greatest width.....	19.8	22.9	23.17	26.7
Plastral concavity..	....	....	1.47	1.8
Gular length........	4.17	5.3	5.47	7.2
Pelvic clearance....	3.6	4.3	3.9	4.5
Tail length........	2.27	2.8	4.00	5.8
Weight in gms.....	....	2,765.	....	5,809.

DESCRIPTION.

Occasionally an old female is found with the caudal worn flat or even cut through, leaving a semicircular nick, as a result of being rubbed by the anal plates of the male. Growth rings are usually visible on full grown specimens, but disappear with age. Scutes become concave by thickening along their edges when age is attained. Occasionally spines about as long as the toenails, extending around the heel, give a starlike contour to the hind foot. The retracted thighs are protected by pointed tubercles, usually in the form of a circle around a large central spine.

HABITS.

One old male was seen with tail hanging down and slowly swinging from side to side with each elephantine step. A large male pushed himself along the ground carrying Robert Heckly and one persisted in crawling under the rung of my chair and tilting me. The little Heckly girls staged "roller skating" races, each standing on two tortoises.

Males utter grunting sounds while courting and recognize one another immediately, possibly by scent which may come from glands beneath the bulbs of the jaws. The long gulars are used by fighting males, which charge one another, their heads retracted. When one manages to ram his protruding gulars into the groin or anterior opening of the opponent's shell, he lifts and twists, often upsetting his antagonist. An overturned tortoise flaps one front leg violently, stopping it suddenly at the most forward position, the momentum jolting it slowly around so that any fixed object within reach may be utilized to right itself. Males may perish if they cannot turn over, since the hot sun is soon fatal. When asleep they sprawl legs and necks in the most grotesque positions, appearing dead. They become tame and inquisitive and seem to enjoy having their heads rubbed.

Fantastic stories of homing instincts may contain a grain of truth as the tortoises usually return to the same burrow nightly. Accounts of treks

or migrations and turtle towns are prevalent. I once saw what appeared to be a migration of *G. berlandieri* in southern Texas and have noted that tortoises are numerous only in restricted localities.

Robert Heckly furnished the following data: "In June, 1934, each of three females laid five eggs and one laid one in holes dug by the hind feet. It took an hour to dig the hole and fifteen minutes to lay the eggs. After depositing an egg, a foot was thrust into the hole, seemingly to roll the eggs from side to side or to pack them in. The hole was then filled and covered by the same process. Four from one female hatched in November, the fifth hatched the following March. The rest were infertile. By October the adults feed infrequently and by December have stopped entirely. They are placed in the cellar under canvas until March when they are brought out during the heat of the day to begin eating and mating, which is over by the last of April. They lay the latter part of June. They have been known to eat dried jackrabbit meat."

Tortoises are eaten during lean years, but no one seemed enthusiastic about the meat. I found the shells of three near the ashes of a small fire in the desert with evidence that the largest carapace had been used for a cooking vessel—an Indian custom. Escaped or liberated specimens are found with a hole drilled in the edge of the shell or a portion of the edge broken out.

Mr. Thomas Hallinan wrote an interesting article on *G. polyphemus* of Florida. Contrasts between the two species are that the present species makes no effort to escape by entering the burrow even if at the entrance, whereas the Florida species scrambles to escape. The burrow is much less steep, usually 12 degrees, starting against a small bank of wind-swept sand at the base of a bush, and humidity is disliked. In Florida the burrows are in damp ground and average fourteen feet long. In California the four-foot burrows are much straighter, the occupant frequently being visible. Never more than one tortoise and no associates, comensals or parasites were found in any burrow in California, whereas the Florida species has associates and parasites. Captive specimens at Thermal are subject to very active ticks which attack the sutures of the carapace instead of the skin and do not attach themselves.

WATER STORAGE.

Persons in the desert say that the tortoise stores water in sacs in each side of the body. The earliest reference noted is by E. T. Cox in the *American Naturalist* of 1881. He stated that while preparing a museum specimen he found on each side a large membranous sac filled with clear water. Dr. R. D. Harwood of San Diego State College kindly dissected two specimens for verification. He found the body cavity full of coelomic fluid and a large, simple, urinary bladder of delicate membrane lying ventrally across the plastron. The sides of the bladder, tucked up between the intestines and marginals on each side, have apparently been mistaken for independent sacs. Dr. Miller thinks that water is produced by metabolism.

YOUNG.

A captive tortoise laid six eggs at Victorville on June 9, 1935. On October 6, I purchased three of these eggs: one pipped, one nearly ready to hatch and one infertile. The remaining eggs were not for sale, but were sufficiently uncovered to see that they were fertile. The three eggs weighed and measured as follows: pipped egg 27.2 gm., 42 x 36.5 mm; fertile egg 30.2 gm., 42 x 37.5 x 35.7 mm; infertile egg with a large air bubble, 27.7 gm., 42 x 36 mm. The shell is hard and unyielding and when blown weighs

3.97 gm. Unfortunately the fertile egg was broken but the embryo was preserved. It was not ready to hatch, having blood vessels surrounding the white and the large yolk. Both this and the living specimen show great scute abnormality. No evidence was found that the eggs are buried singly as stated by Dr. Miller. The embryo lies partly curled and at right angles to the long axis of the egg. It has an egg tooth at the center of the snout with which it makes a ragged opening, parallel to the long axis. The egg tooth apparently is not shed, but flattens out after several months. The head is presented at 45 degrees, the eyes closed, but it opens its mouth threateningly if touched. The hatchling is wider than long, but unrolls and appears nearly normal in five days. A dozen captive babies were observed, all showing pugnacity, bucking forward with open jaws and hissing if touched on the carapace.

The baby hatched October 7, bearing a yolk sac and a small mass of clear, thick, jellylike substance under the plastron. The jelly dried up and the yolk was absorbed in two days. The baby measured in mm:

	1935			1936	
	Oct. 7	Oct. 8	Oct. 11	June 18	Aug. 15
Length	36	41	44	44.5	48
Width	39	37.5	36.5	36.5	42.5
Weight	..	..	19.7	..	..

It drank frequently, but ate almost nothing until May. Efforts to feed were clumsy at first, but by August it was eating tender vegetables, bananas, bread, dry grass with a generous proportion of dirt and slacked lime. It started to grow rapidly in July.

Mrs. Pajanew at Cinco had four that hatched on September 2. One had been sold, but on October 4 the remaining three weighed 23, 23.5 and 25.5 gm. Mr. G. W. Hilton near Coachella had one that hatched on September 15 and his son, John, of Thermal, reported numerous hatchings about August 15. Young specimens are soft, but when 10 cm. in length, or about five years old, seem able to resist carnivores, as several were seen with tooth marks on their shells.

RANGE.

The range was plotted on a map, using records from scientific books and articles, from the writer's observations and from verbal reports where three independent observers of apparent sincerity gave the same locality.

The tortoise does not occur in the Coachella-Thermal district where the temperature is probably higher than in their habitat, but Mr. Hilton's tortoises breed and reproduce well, showing that range restrictions are not due to temperature or low elevation.

The range was found to extend northward into the Panamint Valley and the Shoshone area in Inyo County. There are no records west of the Coachella Valley, so it does not approach San Diego County. It is reliably reported from the Beatty-Bunkerville line southward in Nevada and in Washington County, Utah, and the Phoenix-Florence-Tucson area of Arizona. There are a few Sonora records and one from Tiburon Island. This is a vast area, but great stretches are uninhabited.

In determining the range, tracks, burrows, droppings and dead shells are more convincing proof than a live animal encountered in an unexpected place, as there is always the likelihood that it may have escaped. At least 600 specimens were collected within two miles of Hodge in 1934-1935 ac-

cording to the census of the boys selling them. By driving to likely places, making a hurried reconnaissance and hunting only where tracks abounded the writer was able to collect ten specimens in about six hours—some in burrows and some feeding. They emerge in the forenoon and afternoon during spring and fall.

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20.

Plankton of the Bermuda Oceanographic Expeditions. VII. Siphonophora Taken During the Year 1931[1].

CAPTAIN A. K. TOTTON, M. C.
British Museum (Natural History).

INTRODUCTION.

This is one of a number of papers dealing with the planktonic contents of nets drawn at definite levels and in a definite area off the south coast of Bermuda on the Bermuda Oceanographic Expeditions of the New York Zoological Society. The area chosen was a circle eight miles in diameter, with its center located at 32° 12' N. Lat., 64° 36' W. Long., a point nine miles southeast of Nonsuch Island, Bermuda.[2] The depth at this locality is 1,000 to more than 1,400 fathoms. Further details concerning the nets, position, etc., will be found in ZOOLOGICA, Volume XIII, Numbers 1, 2 and 3.

Captain Totton has kindly identified the hundred-odd vials of siphonophores which I sent him, and Dr. Henry B. Bigelow and Dr. Mary Sears have furnished the faunistic notes. My own share has been only the collecting, and the gathering of the scanty field notes.

WILLIAM BEEBE.

Suborder Calycophorae.
Family Prayidae.
Subfamily Amphicaryoninae.
1. *Amphicaryon acaule* Chun 1888.

MATERIAL: No. 3174; Net 988; 1,000 fathoms; June 2.

COLOR: Lemon yellow in life.

DISTRIBUTION: This species is widespread in the tropical and subtropical belts of the great oceans (for localities see Totton, 1932, p. 330). It was first described by Chun (1888) from the Canaries, but it was not taken again in that general region until 1910, when the *Thor* took it in the Bay of Cadiz (Bigelow and Sears, in press), and in 1913, when the *Hirondelle II* took it in 38° 58' N. Lat., 44° 55' W. Long. (Leloup, 1933). There is only one record of it in the Mediterranean, made by the *Thor*.

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[1] Contribution No. 514, Department of Tropical Research, New York Zoological Society.
[2] For diagram of trawling area, see *Zoologica*, Vol. XXI, No. 9, page 97.

Subfamily Nectopyraminae.
2. *Nectopyramis* sp. nov?

MATERIAL: No. 31942; Net 1120;   400 fathoms; Aug. 3.
No. 311087; Net 1146;   600 fathoms; Aug. 7.
No. 311652; Net 1239;   900 fathoms; Aug. 29.
No. 311767; Net 1259; 1,000 fathoms; Sept. 3.

Subfamily Prayinae.
3. *?Praya dubia* Quoy and Gaimard 1834.

MATERIAL: No. 31509; Net 1063; 300 fathoms; July 8.
No. 311617; Net 1226; 300 fathoms; Aug. 27.

COLOR: Transparent and colorless in life.

DISTRIBUTION: Previous records of *P. dubia* are from Australian waters, from the eastern tropical Pacific (Bigelow, 1911; 1931), and off Valparaiso (Moser, 1925).

4. *?Rosacea cymbiformis* Delle Chiaje 1842.

MATERIAL: No. 31540; Net 1064; 100 fathoms; July 9.

DISTRIBUTION: *Rosacea cymbiformis* has been recorded from all three oceans—in the eastern Atlantic from the tropics northward to the Bay of Biscay (Chun, 1888; Haeckel, 1888; Leloup, 1933), in the South Atlantic (Leloup, 1934; Hardy and Gunther, 1935), in the Philippines (Bigelow, 1919), and in the Indian Ocean (Huxley, 1859; Browne, 1926). There are also frequent records from the Mediterranean whence it was first described.

Family Hippopodiidae.
5. *Hippopodius hippopus* Forskål 1775.

MATERIAL: No. 31305; Net 1036;   200 fathoms; June 25.
No. 31445; Net 1050;   25 fathoms; July 6.
No. 31480; Net 1055;   50 fathoms; July 7.
No. 31733; Net 1089;   50 fathoms; July 18.
No. 311252; Net 1173;   400 fathoms; Aug. 14.
No. 311301; Net 1185;   900 fathoms; Aug. 15.
No. 311473; Net 1201;   800 fathoms; Aug. 19.
No. 311499; Net 1210; 1,000 fathoms; Aug. 20.
No. 311534; Net 1214; 1,000 fathoms; Aug. 21.
No. 311618; Net 1227;   400 fathoms; Aug. 27.
No. 311963; Net 1293;   800 fathoms; Sept. 12.
No. 312066; Net 1308;   100 fathoms; Sept. 16.

COLOR: Transparent and colorless.

DISTRIBUTION: This is one of the more common species found in all the warmer oceans (for summary, see Moser, 1925).

6. *Vogtia glabra* Bigelow 1918.

MATERIAL: No. 311199; Net 1169; 700 fathoms; Aug. 12.

DISTRIBUTION: This species was originally described from the Straits of Florida (Bigelow, 1918) and has since been taken in the eastern side of the temperate Atlantic between the Azores, Canaries and the coast of Portugal and the Gulf of Gascony, as well as in the Mediterranean (Leloup, 1933; Bigelow and Sears, in press). It has never been reported from other oceans, as have other members of this bathypelagic genus.

Family Diphyidae.
Subfamily Abylinae.
7. *Abyla dentata* Bigelow 1918.

MATERIAL: No. 311652; Net 1239;   900 fathoms; Aug. 29.
No. 311767; Net 1259; 1,000 fathoms; Sept. 3.

DISTRIBUTION: This species was first described from the western Atlantic between Bermuda and the American coast (Bigelow, 1918). It has only been noted since then near the Cape Verdes (Moser, 1925, as "*A. quadrata*").

8. *Abylopsis eschscholtzii* Huxley 1859.

MATERIAL: No. 311040; Net 1133;   700 fathoms; Aug. 5.
No. 311534; Net 1214; 1,000 fathoms; Aug. 21.

COLOR: Dull crimson in life.

DISTRIBUTION: This species is widespread over the tropical Pacific and Malayan region (Bedot, 1896; Lens and Van Riemsdijk, 1908; Bigelow, 1911, 1931; Totton, 1932), the Indian Ocean (Browne, 1926), in the South Atlantic (Moser, 1925; Leloup, 1934), also in the tropical Atlantic (Chun, 1888; Mayer, 1900; Leloup, 1934). It has also been taken in the Mediterranean (Leloup, 1933).

9. *Abylopsis tetragona* Otto 1823.

MATERIAL: No. 31883; Net 1107; 400 fathoms; July 27.

DISTRIBUTION: This is one of the commoner species of siphonophores and is found throughout the warmer zones of all oceans (see Moser, 1925).

Subfamily Ceratocymbinae.
10. *Ceratocymba sagittata* Quoy and Gaimard 1827.

MATERIAL: No. 31517; Net 1062;   300 fathoms; July 8.
No. 31920; Net 1117; 1,000 fathoms; July 29.
No. 311250; Net 1174;   500 fathoms; Aug. 14.
No. 311724; Net 1248;   600 fathoms; Sept. 1.
No. 312031; Net 1305;   500 fathoms; Sept. 15.
No. 312067; Net 1308;   100 fathoms; Sept. 16.
No. 312071; Net 1308;   100 fathoms; Sept. 16.
No. 312079; Net 1309;   100 fathoms; Sept. 16.
No. 312169; Net 1322;   300 fathoms; Sept. 18.
No. 312171; Net 1322;   300 fathoms; Sept. 18.
No. 312182; Net 1330; 1,000 fathoms; Sept. 19.

COLOR: Transparent anteriorly; milky white posteriorly.

DISTRIBUTION: This species occurs in the warm parts of the North and South Atlantic (Moser, 1925; Leloup, 1933; 1934), the eastern tropical Pacific (Bigelow, 1911), the Indian Ocean (Browne, 1926), and the Malayan region (Lens and Van Riemsdijk, 1908), and in the Mediterranean, where it was taken for the first time by the *Thor* (Bigelow and Sears, in press).

Subfamily Diphyinae.
11. *Diphyes dispar* Chamisso and Eysenhardt 1821.

MATERIAL: No. 31258; Net 1020; 14 fathoms; June 15.
No. 31304; Net 1035; 100 fathoms; June 25.
No. 31356; Net 1037; 300 fathoms; June 25.
No. 31364; Net 1040; 25 fathoms; June 26.

No. 31409; Net 1045; 25 fathoms; June 27.
No. 31435; Net 1050; 25 fathoms; July 6.
No. 31481; Net 1055; 50 fathoms; July 7.
No. 31507; Net 1055; 50 fathoms; July 7.
No. 31484; Net 1056; 50 fathoms; July 7.
No. 31517; Net 1069; 50 fathoms; July 10.
No. 31598; Net 1069; 50 fathoms; July 10.
No. 31621; Net 1075; 50 fathoms; July 11.
No. 31643; Net 1075; 50 fathoms; July 11.
No. 31650; Net 1079; 50 fathoms; July 14.
No. 31732; Net 1089; 50 fathoms; July 18.
No. 31787; Net 1099; 900 fathoms; July 24.
No. 311211; Net 1169; 700 fathoms; Aug. 12.
No. 311496; Net 1206; 800 fathoms; Aug. 20.
No. 311571; Net 1218; 700 fathoms; Aug. 24.
No. 311625; Net 1230; 900 fathoms; Aug. 27.
No. 312005; Net 1285; 800 fathoms; Sept. 10.
No. 312030; Net 1301; 50 fathoms; Sept. 15.

COLOR: All transparent and colorless except No. 31650, which is described as "siphonophore with long yellow chain."

DISTRIBUTION: This species has been recorded from the warm zones of all oceans.

12. *Chelophyes appendiculata* Eschscholtz 1829.

MATERIAL: No. 311122; Net 1154; 700 fathoms; Aug. 8.
No. 312071; Net 1308; 100 fathoms; Sept. 16.

DISTRIBUTION: This is the commonest of all siphonophores, and is found in all oceans.

13. *Chelophyes contorta* Lens and Van Riemsdijk 1908.

MATERIAL: No. 311534; Net 1214; 1,000 fathoms; Aug. 21.

DISTRIBUTION: This species, first described from the Malayan region, has subsequently been found in the Indian Ocean (Moser, 1925; Browne, 1926), on both sides of the Pacific, off the Great Barrier Reef of Australia (Totton, 1932), in the China Sea (Bigelow, 1913), in the eastern tropical Pacific (Bigelow, 1911), and also in the South Atlantic (Moser, 1925).

14. *Eudoxoides mitra* Huxley 1859.

MATERIAL: No. 311199; Net 1169; 700 fathoms; Aug. 12.

DISTRIBUTION: This species, first described from the Indian Ocean, is well known in the Pacific (Totton, 1932; Bigelow, 1911, 1913), and in the Atlantic (Moser, 1925; Leloup, 1933, 1934; Bigelow, 1918).

15. *Eudoxoides spiralis* Bigelow 1911.

MATERIAL: No. 311534; Net 1214; 1,000 fathoms; Aug. 21.

DISTRIBUTION: This species is cosmopolitan in warm seas; the records include the eastern tropical Pacific (Bigelow, 1911), Japanese waters (Bigelow, 1913), off the Great Barrier Reef of Australia (Totton, 1932), the Indian Ocean (Browne, 1926), many localities in the South Atlantic, south to Latitude 45° S. (Moser, 1925; Leloup, 1934); likewise the tropical and subtropical North Atlantic, northward to the vicinity of the Cape Verdes (Leloup, 1934) on the one side and in the region of Cape Hatteras, Bermuda and the Bahamas (Bigelow, 1918) on the other. It has also been taken in the Mediterranean.

16. *Lensia conoidea* Keferstein and Ehlers 1860.

MATERIAL: No.   3174; Net   988; 1,000 fathoms; June 2.
No. 311816; Net 1263;   800 fathoms; Sept. 4.

COLOR: Lemon yellow in life.

DISTRIBUTION: Since *L. fowleri* and *L. subtiloides* have often been treated as synonyms of *L. conoidea*, it is impossible to learn its range from published accounts. There are definite records of it from the North Pacific, the Malayan region, the Gulf Stream, and the coast of Norway. It is likely that it occurred among the specimens listed as *"truncata"* from the South Atlantic (Moser, 1925; Leloup, 1934; Hardy and Gunther, 1935), and in the Mediterranean (Moser, 1925; Leloup, 1933). It was taken in the latter sea in abundance by the *Thor* (Bigelow and Sears, in press).

17. *Lensia multicristata* Moser 1925.

MATERIAL: No. 311415; Net 1195; 800 fathoms; Aug. 17.
No. 311780; Net 1258; 900 fathoms; Sept. 3.

DISTRIBUTION: *Lensia multicristata* Moser is widespread in the eastern tropical Pacific (Bigelow, 1911), in the Indian Ocean (Browne, 1926), in the South Atlantic (Moser, 1925; Leloup, 1934), and as far north in the North Atlantic as the Bay of Biscay (Bigelow, 1911a), as well as in the Mediterranean (Bigelow and Sears, in press).

18. *Lensia profunda* sp. nov.[3]

MATERIAL: No. 311377; Net 1190; 900 fathoms; Aug. 16.
No. 311601; Net 1217; 600 fathoms; Aug. 24.

19. *Lensia* sp.

MATERIAL: No. 311534; Net 1214; 1,000 fathoms; Aug. 21.

20. ?*Chuniphyes multidentata* Lens and Van Riemsdijk 1908.

MATERIAL: No. 311199; Net 1169; 700 fathoms; Aug. 12.
No. 311510; Net 1207; 900 fathoms; Aug. 20.
No. 311968; Net 1291; 600 fathoms; Sept. 12.
No. 312008; Net 1298; 800 fathoms; Sept. 14.

COLOR: Transparent and colorless in life.

DISTRIBUTION: The bathypelagic species, *C. multidentata*, was first described from Malayan waters. Later, it has been recorded from the eastern tropical Pacific (Bigelow, 1911, 1931), the offing of California (Bigelow and Leslie, 1930), the Eastern Sea between Japan and China (Bigelow, 1913), near the Philippines (Bigelow, 1919), and on both sides of the Atlantic— south to South Georgia, and north to the Bay of Biscay (Bigelow, 1911a; Moser, 1925; Leloup, 1933, 1934; Hardy and Gunther, 1935). There is only one record of it within the Mediterranean (Leloup, 1933).

Suborder Physophorae.
Family Forskalidae.
21. *Forskalia* sp.

MATERIAL: No.   3110; Net   980; Surface; May 17.
No. 311300; Net 1185; 900 fathoms; Aug. 15.

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[3] See MS. *Discovery* Report.

No. 311301; Net 1185; 900 fathoms; Aug. 15.
No. 311511; Net 1207; 900 fathoms; Aug. 20.

COLOR: No. 3110 was described as "lemon-colored," No. 311300 as "orange-red," and No. 311511 as "black-lined."

Family Agalmidae.
22. *Agalma elegans* Sars 1846.

MATERIAL: No. 31492; Net 1054;   25 fathoms; July 7.
No. 312117; Net 1314; 600 fathoms; Sept. 7.

COLOR: Transparent and colorless.

DISTRIBUTION: This species is well known from the Mediterranean, from the coasts of Europe as far north as Norway and along the eastern coast of North America from Cape Cod to the West Indies, and in the eastern tropical Pacific (Bigelow, 1911), as well as in Malayan waters (Bedot, 1896) and the Indian Ocean (Browne, 1926).

23. *Agalma okeni* Eschscholtz 1825.

MATERIAL: No. 31210; Net 1018; 900 fathoms; June 15.
No. 31314; Net 1038; 300 fathoms; June 25.
No. 31976; Net 1128; 400 fathoms; Aug. 4.
No. 311616; Net 1226; 300 fathoms; Aug. 27.
No. 312068; Net 1308; 100 fathoms; Sept. 16.
No. 312071; Net 1308; 100 fathoms; Sept 16.
No. 312085; Net 1310; 300 fathoms; Sept. 16.
No. 312088; Net 1311; 300 fathoms; Sept. 16.
No. 312170; Net 1322; 300 fathoms; Sept. 18.

COLOR: Nectophores transparent, siphosomes coral and white in life.

DISTRIBUTION: This species occurs in the warmer regions of all the great oceans and has occasionally been taken in the Mediterranean and Red Sea.

24. *Stephanomia amphitridis* Péron and Lesueur 1807.

MATERIAL: No.   3152; Net   984;   600 fathoms; June 2.
No.   3153; Net   984;   600 fathoms; June 2.
No. 311013; Net 1133;   700 fathoms; Aug. 5.
No. 311040; Net 1133;   700 fathoms; Aug. 5.
No. 311091; Net 1143;   500 fathoms; Aug. 7.
No. 311092; Net 1143;   500 fathoms; Aug. 7.
No. 311112; Net 1149;   500 fathoms; Aug. 8.
No. 311534; Net 1214; 1,000 fathoms; Aug. 21.
No. 311859; Net 1274;   900 fathoms; Sept. 7.
No. 312196; Net 1326;   600 fathoms; Sept. 19.

COLOR: Varying from crimson to pink and orange.

DISTRIBUTION: This species, originally described from the Atlantic, has also been recorded from the Pacific, the Malayan region and probably from Ceylon.

Subfamily Nectaliinae.
25. *Nectalia loligo* Haeckel 1888.

MATERIAL: No. 311040; Net 1133; 700 fathoms; Aug. 5.
No. 311113; Net 1149; 500 fathoms; Aug. 8.

No. 311494; Net 1205; 700 fathoms; Aug. 20.
No. 311570; Net 1218; 700 fathoms; Aug. 24.
No. 311571; Net 1218; 700 fathoms; Aug. 24.
No. 311673; Net 1236; 600 fathoms; Aug. 29.
No. 311688; Net 1243; 700 fathoms; Aug. 31.
No. 311968; Net 1291; 600 fathoms; Sept. 12.
No. 311984; Net 1291; 600 fathoms; Sept. 12.
No. 311964; Net 1292; 700 fathoms; Sept. 12.
No. 311966; Net 1292; 700 fathoms; Sept. 12.

COLOR: Crimson and transparent.

DISTRIBUTION: Few specimens of this species are on record. The type came from the Canary Islands and subsequent records are two specimens taken by the Plankton Expedition in 3° 6′ N. Lat., 33° 2′ W. Long., and the northern border of the Gulf Stream south of Iceland, one from Orotava, one from the eastern tropical Pacific, and from the South Atlantic (Moser, 1925).

Subfamily Anthophysidae.
26. *Anthophysa formosa* Fewkes 1882.

MATERIAL: No. 311187; Net 1162; 800 fathoms; Aug. 11.
No. 311281; Net 1178; 900 fathoms; Aug. 14.
No. 311367; Net 1188; 500 fathoms; Aug. 16.
No. 312205; Net 1325; 500 fathoms; Sept. 19.

COLOR: Lemon yellow and white.

DISTRIBUTION: This is the member of this genus found in the Atlantic, and may eventually prove to be identical with *A. rosea* Brandt. It is known from the Gulf Stream in the western side of the North Atlantic, from the Sargasso Sea, from the South Atlantic, where it was taken by the *Challenger,* from the vicinity of the Canaries and from the Mediterranean.

27. *Athorybia rosacea* (Forskål 1775) Eschscholtz 1829.

MATERIAL: No. 311008; Net 1136; 1,000 fathoms; Aug. 5.

28. *Athorybia* sp.

MATERIAL: No. 312071; Net 1308; 100 fathoms; Sept. 16.

Suborder Rhizophysaliae.
Family Rhizophysidae.
29. *Rhizophysa* sp.

MATERIAL: No. 31719; Net 1084; 25 fathoms; July 15.
COLOR: Pink.

Family Physalidae.
30. *Physalia physalis* Linné 1758.

MATERIAL: Often taken at the surface.

DISTRIBUTION: This is the common Portuguese-man-of-war of the warmer parts of the Atlantic Ocean.

Suborder Chondrophorae.

Family Porpitidae.

31. *Porpita umbella* O. F. Müller 1776.

MATERIAL: Occasionally taken at the surface.

DISTRIBUTION: This species is the one found in the warm waters of the Atlantic Ocean. It may prove to be the same as *P. porpita* Linné from the Indian Ocean, but it is probably distinct from *P. pacifica* Lesson.

Family Velellidae.

32. *Velella velella* Linné 1775.

MATERIAL: Occasionally taken at the surface.

DISTRIBUTION: This species is found in the warmer waters of the Atlantic and Pacific. On further study, it may prove identical with the *Velella* of the Indian Ocean.

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21.

The Female Bitterling as a Biologic Test Animal for Male Hormone[1].

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&

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(Plate I; Text-figure 1).

Introduction.

A number of different methods of testing for male hormone have been proposed (1) with the capon, the guinea pig, the rat, and the castrated male bitterling (2) as test animals. None of these tests has been very satisfactory. Recently Witschi (3) has described a change in the color of the bill of the sparrow after injections of male hormone and has suggested this as an indicator. The capon test is the one most commonly employed. Injections of potent material cause a growth of comb and wattles in four or five days. The measurement is not simple nor is it standardized (4). Injections do not produce constant results and for each test six animals should be used (5). Thus a considerable amount of expense, space, care, and attention are required for a single test. Castration must be complete and the bird can not be used again after a positive reaction until the comb has regressed.

It therefore seems evident that a more convenient method of detecting and measuring the male hormone would be of considerable value. The ovipositor lengthening of the female bitterling appears to furnish a simple biological reaction for this hormone, as the present experiments will indicate. This lengthening of the ovipositor of the female bitterling (Pl. I, Fig. 1) was first elicited by Ehrhardt and Kuhn (6) and, shortly after, independently by Fleischmann and Kann (7), but they ascribed this reaction to follicular hormones. It was later suggested as of possible use in diagnosing pregnancy by Kanter, Bauer, and Klawans (8). Although these authors did not definitely state that it was a test for pregnancy, their paper intimated this use so clearly that a number of laboratories accepted this viewpoint. It was soon shown that it could not be so considered (9, 10, 11), since urines from non-pregnant females, women in the post-climacteric period, and even from men gave positive reactions. Occasionally a pregnant women's urine would be negative. That this test is produced by male hormone will be shown below (12).

EXPERIMENTAL.

The female bitterling[2] develops an ovipositor which depends from the ventral margin of the body slightly anterior to the origin of the anal fin. In the quiescent state the ovipositor is seldom visible, but in those individuals in which it is visible out of season it is very small and rarely reaches 5 mm. in length. During breeding activity the organ is prolonged until it may reach 5 cm. in length (Pl. I, Fig. 2) and at spawning it is inserted into the inhalent siphon of a mussel, usually *Unio or Anodonta,* and the ova extruded into the gill-folds. Fertilization is effected by sperm which is liberated near and drawn into the inhalent siphon of the mussel and passed over the embedded ova. Hatching occurs within the gill-folds and the fry liberate themselves, in a post-larval state, two or three weeks after oviposition.

Description of Test.

To a small aquarium is added 4 liters of water, 2 liters from a stock tank and 2 liters from the tap. Two female bitterlings are placed in the tank and kept there 24 hours before introducing the material to be tested. At the end of the 24-hour period readings are made of the size of the ovipositor. The scale used is as follows: If the ovipositor is not visible the reading is 0; if the length of the ovipositor equals the length of the first ray of the anal fin the reading is 10; an ovipositor which reaches halfway down the first ray is 5; etc. (That is, the length of the ovipositor is compared to that of the first ray of the anal fin in equal units running from 0 to 10. (Text-fig. 1).) No fish with ovipositors exceeding 3 on the scale, before the addition of any test material, are used.
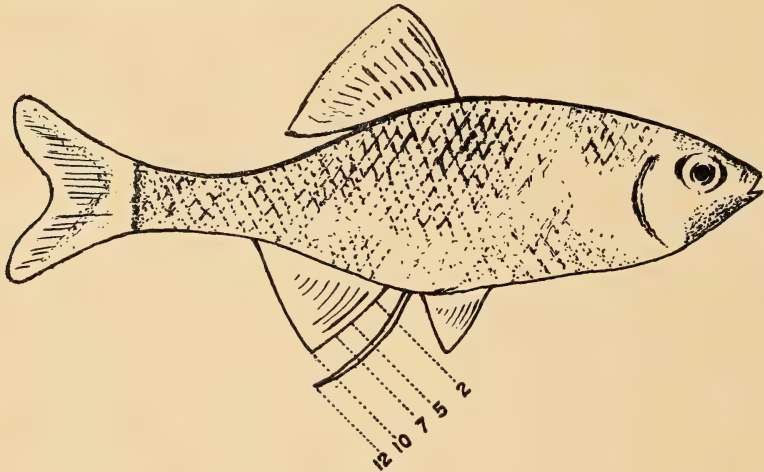
Text-figure 1.

Diagrammatic representation of scale used in reading length of ovipositor of female bitterling.

Ovipositor readings are taken at 24, 48, and 72 hour intervals and maximum growths under these conditions are usually observed at the second reading.

We tentatively define a bitterling unit as the amount of material which, when added to a tank containing 4 liters of water and 2 female bitterlings,

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[2] We are greatly indebted to Mr. C. M. Breder, Jr., of the New York Aquarium, for advice and suggestions in respect to the fish.

produces an increase in the length of the ovipositor of one or both fish of 7 or more on the scale within 48 hours.[3] For assay it is suggested that a series of dilutions may be set up and the lowest dilution giving a positive reading may be considered to contain at least one unit, providing a positive reaction is also given in the next higher dilution.

In this work the European bitterling (*Rhodeus amarus*) was used. Kanter et al (8) used the Japanese bitterling (*Acheilognathus intermedium*) and suggest differences between the two species. However, comparative initial experiments with pregnancy urines conducted under identical conditions at the same time with both species by Coates (unpublished) did not seem to indicate any substantial difference between them.

An important observation is that female bitterlings which have been used throughout the year seem quite refractory during the late spring and summer months. From about May 15 until August 15 they react very weakly, as a rule, to preparations which at other times are definitely effective. This has been noted by other investigators. It may be a temperature effect. Gottlieb (11) working in Quebec, got good results throughout the breeding season, i. e., May-July. Whether temperature regulation or some other means may be devised to overcome this difficulty remains to be seen. In the meantime, this seasonal variation must be taken into account.

The preliminary experiments (9) already referred to, showed that urines from non-pregnant females, pregnant females, women in post-climacteric period, and men gave positive reactions in many instances. We have since extended these observations and these indicate that most normal urines from young adult males cause reactions if a large enough quantity can be used without harm to the fish. This suggested that the responsible factor might not be the follicular hormones. Moreover, the fact that urines from women 5-6 years after menopause still gave ovipositor reactions in some cases gave further support to this hypothesis. We also conducted a large number of experiments with commercial medicinal female sex hormone preparations and obtained very irregular results. Up to this point the results did not definitely indicate that the responsible factor is hormonal in nature. It might possibly be some common urinary constituent, such as creatinine, uric acid, or indican.

It was therefore seen to be necessary to determine what type of compound present in urine caused the reaction. Urine was first dialysed with the following results:

Experiment 1: Urine was obtained from a healthy male subject whose urines, previously tested, had invariably given positive results. 20 cc. was dialysed in a cellophane membrane against 40 cc. of distilled water in the refrigerator, for 24 hours. An undialysed portion was kept at the same temperature for the same period. 16 cc. of the dialysed urine, 32 cc. of the dialysate, and 16 cc. of the untreated urine were each added to 4 liters of water containing 2 fish. Positive reactions were noted in 48 hours in the tanks to which had been added the dialysed urine, as well as the control, but not in that containing the dialysate.

Experiment 2: A similar experiment was done with pregnancy urine. Similar results were obtained but it was noted that the dialysed urine was distinctly ammoniacal. This led to the suspicion that an excess of ammonium compounds might be the causative factor. An experiment was therefore conducted in which ammonium hydroxide was added to the water containing 2 fish. Results of this test proved to be negative. It thus seemed evident that the ovipositor stimulating substance is not an ammonium salt and is not dialysable. This also rules out many common urinary constituents, such as inorganic salts, creatinine, urea, uric acid, etc.

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[3] This differs slightly from our originally suggested definition (12), i.e., that the ovipositor must reach the end of the fin. The present definition allows for differences in the initial length of the ovipositor.

The next step was to determine whether it belonged to any of the classes of sex hormones. Even though we had shown its incapability of being used as a pregnancy indicator, it was necessary to rule out definitely the anterior-pituitary-like hormone. This was easily done by boiling some "positive" urine and ascertaining that the resulting urine was still positive. The anterior-pituitary-like hormone ("AP-L") is heat labile.

The following experiment showed that the responsible factor is chloroform-soluble.

Experiment 3: 500 cc. of mixed urine from 20 pregnant women was treated with 20 cc. of conc. HCl and was then extracted three times with 100 cc. portions of chloroform in a separatory funnel. An emulsion formed which was cleared by the addition of 500 cc. of ether. The chloroform-ether layer was drawn off, evaporated on a steam bath, and the brown gummy residue dissolved as far as possible in 65 cc. of water containing 0.5 cc. of 10% NaOH. This was added to 7 liters of water containing 2 female bitterlings. In 16 hours both fish showed marked positive reactions. 35 cc. of the extracted urine from which the chloroform had been removed gave no reaction under similar conditions in 72 hours. This experiment led us to the conclusion that the effective factor is soluble in chloroform and to the impression that it is similar to the ovarian follicular hormones.

It therefore seemed logical to expect that crystalline "theelin" or "theelol," or both, would produce this reaction. We were fortunately able to obtain a small amount of each from Dr. Edward A. Doisy and they were tested and showed very slight effects, if any, on the ovipositor.

As is well known, the chloroform and ether soluble hormones of urine comprise the male as well as the female sex hormones, i. e., androsterone and estrins. We consequently subjected urine to a rough separation of these substances, using the method of Funk, Harrow, and Lejwa (13) with the modifications of Butenandt and Tscherning (14) and Kochakian and Murlin (15). A typical experiment is the following:

Experiment 4: 18 liters of mixed male urine was made acid to Congo Red and 360 cc. conc. HCl added. The mixture was concentrated on a steam bath to 1,800 cc. 500 cc. chloroform was added and the mixture refluxed for 12 hours on a steam bath. The aqueous fraction was discarded and the chloroform extract evaporated to dryness. The gummy residue was then dissolved in ether and shaken with 2N KOH until no further color appeared in the aqueous phase. The washings were extracted with ether and the ether solutions combined, and evaporated to dryness. The residue was refluxed with 50 cc. 3N KOH in methyl alcohol for 2 hours. After cooling, 2 liters of water was added and extracted repeatedly with ether. The aqueous fraction was saved. The extract was washed with water, dilute acid, and finally again with water. This constitutes the male hormone fraction.

The aqueous fraction was treated with HCl until acid to Congo Red and an additional 20 cc. HCl were added. The mixture was heated on a steam bath for 1 hour and extracted repeatedly with ether. The ether extract was washed with water, dilute alkali, and finally with water. This yields the female hormone fraction.

Each fraction was now tested for its ovipositor-lengthening effect on the female bitterling, as follows:

Experiment 5: Ether solutions equivalent to 64 cc. of urine were placed in a mortar and the ether permitted to evaporate. The oily residue in each case was emulsified with acacia and water and added to a tank of 2 bitterlings in the usual manner. After 18 hours positive reactions were seen to have been produced by the *male fraction* and none by the *female fraction*.

That the *male fraction* actually contained male hormone was substantiated by injection of a cotton-seed oil solution of it into a capon. A posi-

tive result was seen, whereas a similar test with the female fraction was negative. Both fractions, however, produced estrogenic effects when injected into immature female mice. This harmonizes with the previous experiences of many investigators (16) who found estrogenic effects with male hormone preparations. Recent work indicates, however, that highly purified or synthetic androsterone is non-estrogenic by the vaginal cornification test (17). Hence, the estrogenic effect of our male fraction may have been due to admixture of impurities.

The question now arose as to why pregnancy urines should be more potent and more constant in their activity than urines from males and non-pregnant females. We therefore repeated the above experiment, using mixed pregnancy urines. Here again the bitterling test was positive with the male fraction and negative with the female.

The facts thus indicate that the ovipositor-lengthening factor of urine is present in the male fraction, but proof that one of the male hormones is responsible was still lacking. This gap in the proof has recently been filled by the use of *synthetic* preparations[4]. Despite the fact that our experiments were performed during the refractory season we were successful in showing the efficacy of these products. At the same time we can also report what seems to be a more suitable solvent which is harmless to the fish and which offers a much better menstruum for these sterols than the acacia which we had formerly employed as an emulsifying agent. This is propylene glycol, suggested to us by Dr. Warren M. Cox, Jr., of the Research Laboratory of Mead Johnson & Co.

Experiment 6: 4 mg. of synthetic androsterone (Schering) and 3 mg. of synthetic testosterone (Schering) were each dissolved in 5 cc. of propylene glycol (Eastman) under the influence of slight heating. Aquaria with two bitterlings in 4 liters of water had been set up the previous day. All had extremely small ovipositors (0 to 2). One liter of water was removed from the aquarium and the propylene glycol solution of the sterol added quickly and shaken vigorously. It was then added to the aquarium from which the water had been taken. A third aquarium with the same amount of propylene glycol was observed as a control.

A positive result was noted in the bitterlings exposed to both the crystalline androsterone and testosterone. Propylene glycol alone was negative. The fish exposed to androsterone were greatly weakened by this substance but the testosterone had very little systemic effect.

In the fall when the animals were found to be in a normally reactive state both of these synthetic products were re-tested. It was found that 0.8 to 1.2 mg. of androsterone (18) produced positive reactions in 48-72 hours, whereas small amounts were never effective and larger doses yielded variable results. The larger doses seemed to have the same depressing effect as was mentioned above. Crystalline testosterone also gave uniformly positive reactions at a certain dosage (0.6-0.8 mg.) (unpublished data) whereas larger and smaller amounts were usually ineffective. Again it may be stated that a positive reaction is one in which the lengthening of the ovipositor totals 7 points or more on the scale. Many of the negative tests at other dosages showed slight effects, i. e., a lengthening of less than 7. It must also be pointed out that the results with these crystalline products appeared more slowly than when urine had been used, presumably because they are in a different physical state. From these experiments *it is evident that the ovipositor-lengthening phenomenon is due to male hormones.* There can be no suspicion of admixture of urinary impurities in these synthetic products.

Confirmatory evidence has also been obtained by testing male hormone concentrates kindly furnished by Dr. Benjamin Harrow of the College of

the City of New York. This material, an oily solution of the male hormone fraction of male urine, has an activity of 10 capon units per cc., each cubic centimeter representing 1,000 to 1,150 cc. of urine. As little as 0.1 cc. added to an aquarium of female bitterlings gives a positive reaction in 48 hours. The minimum effective dose has not yet been reached.

Technique for Assay of Urine.

In attempting to determine the amount of male hormone in normal male urine, the following procedure was employed, using normal male medical students as subjects: For each assay, 4 aquaria were set up, containing 4 liters of water and 2 female bitterlings in the usual manner. To each tank was then added 10 cc., 25 cc., 50 cc., and 100 cc. portions of urine respectively. 24 hour samples of urine were used. The smallest amount causing a positive reaction was considered to contain one unit. The number of units in a 24-hour sample was then calculated. It was noted that in many instances the urine was toxic and even fatal in amounts from 50 to 100 cc. Various methods have been tried in the attempt to detoxicate the urines and finally it was found that dialysing is all that is necessary (19). By this means dialysed urines representing as much as 200 cc. of the original may be used without any ill effects whatever. Ordinarily the procedure is the following: Measured amounts of urine, usually 200 cc., are dialysed in membranes of cellophane ("plain transparent" not "moisture-proof") against running tap water for 18-24 hours. The volumes are then measured and amounts equivalent to 10, 25, 50, and 100 cc., respectively, of the original urine are added to 4 aquaria, each of which contains 2 female bitterlings. The ovipositors of the fish must have been read on the preceding day and also just before addition of the dialysed urine. Subsequent readings are made in 24, 48, and 72 hours, and the number of units determined in the manner suggested above. The average excretion of male hormone is about 35 bitterling units per day with a range of approximately 15 to 75 b.u. (see Table I). Further work to check and enlarge this series is in progress.

TABLE I.

Daily excretion of male hormone by normal adult males.

Number of 24-hour urine specimens	Number of cc. of urine which, when added to 4 liters of water, produce a positive reaction	Bitterling units excreted daily
5	10—15	75—120
15	25—35	24—45
10	75—100	9—22

Preliminary tests have indicated the unreliability of using casual specimens for even rough quantitative work. We have noted that successive samples obtained during the day from the same individuals have been exceedingly variable in the amounts of hormone excreted and some samples are even entirely devoid of the hormone. Apparently 24-hour samples of urine are needed in order to determine the output of this hormone with any degree of accuracy.

DISCUSSION.

Evidently neither theelin nor theelol is responsible for the reaction, nor are various cholane derivatives which have thus far been tested, such as cholesterol, ergosterol, and sodium taurocholate (20). Several of these

give slight reactions, which suggest the possibility that other cholane derivatives may be found which will react as well as the male hormone. Up to the present the test seems to be specific for male hormone.

In support of this we may cite several references to the literature. Glaser and Haempel (21) compared the effect of a follicular hormone preparation with several other preparations, including a male hormone product, "testosan forte." The technique of the experiments included placing males and females in the same aquarium. The results showed slight growth of ovipositors in those females subjected to the male as well as the female hormone, although the latter gave stronger results. The data given seem inconclusive, however. Glaser and Haempel conclude that certain secondary sex characteristics are influenced by both male and female hormones. Among these are the lengthening of the ovipositor of the female bitterling and the growth of the comb and wattles of the capon. This work was subjected to criticism by Fleischmann and Kann (22). They confirmed Glaser and Haempel's contention that "testosan forte" gave positive results with the female bitterling but they are of the opinion that this is due to an admixture of follicular hormone. In support of this they state that this male hormone preparation also gives the Allen-Doisy test on the mouse. A more concentrated male hormone preparation, "Proviron" (Schering) had the same action, i.e., positive reactions with both the fish and mouse tests, whereas crystalline "Proviron" reacted negatively with both. We suggest that this negative result may have been a result of incomplete solution or improper emulsification of the substance. The authors do not state the menstruum or method employed for this purpose.

An interesting contribution has also been made by Ehrhardt and Kuhn (23). In a long series of experiments they come to the conclusion that the ovipositor-lengthening factor and the estrus hormones are not identical, although both have a number of properties in common, i.e., solubility in organic solvents, heat stability, absorption on charcoal, etc. Some points of difference are the following: in the urine of pregnant mares are large quantities of estrus hormone, but small quantities of the ovipositor-lengthening factor. Non-pregnant women, on the other hand, excrete a urine with just the opposite characteristics. Eight hundred units of technical (i.e., impure) estrus hormone give a better ovipositor-lengthening result than several thousand units of crystalline estrus hormone. The blood serum of the pregnant woman gives a strong Allen-Doisy test but a weak bitterling test. Their preparations thus did not quantitatively show parallel results when tested with the fish and with the mouse. Although they believe the two phenomena to be due to two distinct substances they are of the opinion that one is a transformation product of the other. Ehrhardt and Kuhn's work harmonize with the contention that the male hormone is the responsible factor for this phenomenon.

We propose to assay urines and other biological fluids under various physiological conditions and from pathological cases for their male hormone content by this method. The method should also be of value in assaying male hormone products to be used therapeutically.

SUMMARY.

The lengthening of the ovipositor of the female bitterling produced by the administration of human urine has been found to be due to the male hormone present therein. Confirmation of this is shown by positive effects caused by crystalline androsterone and testosterone. A bitterling unit is provisionally defined and a method of measuring the ovipositor is described.

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EXPLANATION OF THE PLATE.

PLATE I.

Fig. 1. Female bitterling, showing elongation of ovipositor: considered a minimum positive reaction.

Fig. 2. Female bitterling, showing elongation of the ovipositor in the process of natural ovipositation.

FIG. 1

FIG. 2

THE FEMALE BITTERLING AS A BIOLOGIC TEST ANIMAL FOR MALE HORMONE.

22.

Some Tropical Fishes as Hosts for the Metacercaria of *Clinostomum complanatum* (Rud. 1814) (= *C. marginatum* Rud. 1819).

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(Plates I & II).

The following fishes received by the New York Aquarium were found infected with the yellow grub stage of *Clinostomum*: *Chriopeops goodei* (Jordan) from Florida; *Mollienisia velifera* (Regan) from Yucatan; *Piabucana* sp. from the Amazon drainage; *Corynopoma riisei* Gill from British Guiana; *Nannostomus trifasciatus* Steindachner from the Tucantins, a tributary of the Amazon; *Lebistes reticulatus* (Peters) from out-door pools in Florida; *Hypopomus artedi* Kaup from the Amazon drainage in eastern Brazil; and *Sternopygus macrurus* (Bloch and Schneider) from the Amazon drainage.

In some instances the fishes showed no infection when they arrived, and only after they had been in the Aquarium for some time did the cysts appear. Whether the fishes were originally infected and growth of the parasite had taken place in the tanks, or whether the fishes acquired the infection in the tanks is difficult to determine. Examination of snails and water of the aquaria showed no fork-tailed cercariae.

In cases of severe infection the death of the host resulted. The trematodes were usually encysted in the fish, and in *Corynopoma riisei* the grub was embedded deep in the peculiar transparent muscle of the body (Pl. I, Figs. 1 & 2). In the gymnotid, *Sternopygus macrurus,* 16 cysts were found distributed along both sides of the base of the elongated ventral fin.

Observations on the "guppy'" showed that, since this species is not influenced by seasonal changes, the cysts are not deserted as reported by Ward (1918) for northern forms. The parasites were present on the fish (Pl. II, Fig. 3) for more than a year. In one of the specimens found dead, moribund metacercariae were still in the cysts. Many of the temperate zone fishes in the Aquarium were also found infected with the metacercariae of *Clinostomum.* In the majority of instances the worms were encysted on the membrane between the rays of the fins. These cysts appeared in the spring and in winter were absent.

Examination of the parasites showed no morphological differences between the metacercariae found on tropical forms and those of temperate zone species. In all instances the worms have been identified as *C. complanatum* (Rud. 1814) (= *C. marginatum* Rud. 1819) (Pl. II, Figs. 4 & 5).

The metacercaria of *C. complanatum* has been found on a large number of fish hosts throughout the world. As *C. marginatum* it has been reported by several investigators from the following neotropical fishes (see Baer 1933): *Adnia (Adinia?) dugesi* (Bean), *Callichthys asper* Quoy and

Gaim., *Poecilia vivipara* Bloch and Schneider, *Chaetosomus brachyurus* (Kner), *Cynodon scomberoides* (Cuv.), *Satanoperca papatera* (Heck.), *Chaetobranchus flavescens* Heck., *C. gulosus* (Cuv. and Val.), *Crenicichla johanna* Heck., *Crenicichla saxatilis* (Linn.).

These are definitely Central and South American species of fishes, but because of the terminology employed, it is difficult to determine which form is referred to, since in the present day usage some of the above genera have been split up and others have been discarded. In North America the metacercaria has been reported from a large number of fishes, several species of amphibians (*Rana clamitans, R. pipiens,* etc.), and, according to Hopkins (1933), the parasite was found in a snake (*Thamnophis radix* (Baird)) by van Cleave.

The following are some of the North American fishes found infected: *Perca flavescens* (Mitchill)[1] (yellow perch); *Aphredoderus sayanus* (Gilliams) (pirate perch); *Micropterus dolomieu* Lacépède[1] (small mouthed black bass); *M. salmoides* (Lac.)[1] (large mouthed black bass); *Ambloplites rupestris* (Raf.)[1] (rock bass); *Lepomis pallidus* (Mitchill)[1] (bluegilled sunfish); *L. auritus* (Linn.)[1] (red-breasted sunfish); *L. cyanellus* Raf.[1] (green sunfish); *Eupomotis gibbosus* (Linn.)[1] (common sunfish); *Catostomus commersoni* (Lac.)[1] (common sucker); *Pimephales promelas* Raf. (fathead minnow); *Semotilus astromaculatus* (Mitch.) (horned dace); *Ameiurus nebulosus* (Le Sueur)[1] (common bullhead); and *Salvelinus fontinalis* (Mitch.) (brook trout). In Europe Ciurea (1911) reported the yellow grub of *C. complanatum* on *Perca fluviatilis* Linn., and Maccagno (1933) found it on the loach, *Cobitis taenia* Linn. In Japan Yamaguti (1933) found it under the skin and flesh of *Carassius carassius* Linn., *Pseudogobio esocinus,* and *Acheilognathis intermedia.*

The following are other species of *Clinostomum* described from fishes:

1. *C. heterostomum* (Rud. 1809) from European fishes, and from an unidentified species taken in the Vaal river, Africa (Monnig 1926).

2. *C. dimorphum* (Diesing 1850) from many of the tropical fishes mentioned above.

3. *C. dictyotum* (Monticelli 1893) (= *Clinostomatopsis reticulata* (Looss 1885)) from an unidentified silurid of Costa Rica.

4. *C. africanus* Stoss. from the intestine of an unidentified fish of the French Congo (see Galli-Valerio 1906).

5. *C. piscidium* Southwell and Prashad 1918 from *Trichogaster fasciatus* and *Nandus nandus* of Ceylon, and from *Trichogaster pectoralis* and *T. trichopterus* of Siam (Pearse 1933).

6. *C. intermedialis* Lamont 1920 from the silurid, *Rhamdia quelen* Quoy and Gaimard.

7. *C. chrysichthys* Dubois 1930 from *Chrysichthys kingselyi* Gunth., a silurid of Angola.

8. *C. clarias* Dubois 1930 from *Clarias angolensis* Steind., a silurid of Angola.

9. *C. dalgi* Tubangiu 1933 from the eye-socket and pericardium of *Ophiocephalus striatus* Bloch., a Philippine fish.

Four orders of fishes are represented by the hosts of *Clinostomum* reported in the literature. Arranged according to the number of species found infected, these are: Ostariophysii, Acanthopterygii, Haplomi, and Isospondyli. With the exception of the Isospondyli, all are basically pond fishes. In the great majority of ponds the same relationship among these orders probably exists; that is, the Ostariophysii includes the largest number of species to be found in such a habitat, the Acanthopterygii the next largest, etc.; and likewise as to number of individuals. The Isospondyli is repre-

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[1] Species present in the Aquarium on which *Clinostomum* was found.

sented by one species, *Salvelinus fontinalis* (brook trout). It is altogether possible that this form became infected during an excursion into still water, which it sometimes makes.

It is not surprising to find that pond fishes show the highest incidence of infection. The nature of the cercaria of *Clinostomum* is such that it would be mechanically difficult to infect fishes in a fast stream. These cercariae are fork-tailed organisms which float at the surface. The pond fishes, moreover, are more sluggish than the stream forms, thus making it more feasible for the cercariae to penetrate the skin.

The genus *Clinostomum* was erected by Leidy (1856) for a metacercaria found encysted in the skin of the common sunfish, *Pomotis vulgaris* C. and V., *Eupomotis gibbosus* (Linn.), and in the intestine of *Esox* sp. This species he called *C. gracile* and designated it as the type of the genus. *C. gracile* Leidy 1856, however, is considered a synonym of *C. complanatum* (Rud. 1814), an adult form taken from a heron (*Ardea cinerea*) by Rudolphi and described by him as *Distomum complanatum*. Braun (1901) made *C. complanatum* the type of the genus because Leidy's description was inadequate and because the original type was lost. There is no doubt, however, that the yellow grub, called *C. marginatum* by most North American investigators and even now found on the type host and in the type locality, is Leidy's *C. gracile*. Braun (1899) considered *C. marginatum* (Rud. 1819) a synonym of *C. complanatum* (Rud. 1814) because the two were morphologically the same and were found as metacercaria on fishes and as adults in the same genus of birds (*Ardea*). Baer (1933) expressed the same opinion and added that the geographical distribution of the two was alone not sufficient to warrent regarding them as distinct species.

According to Baer (1933) *C. heterostomum* (Rud. 1809) = *Euclinostomum heterostomum* (Rud. 1809), and *C. dimorphum* (Diesing 1850) = *Ithyclinostomum dimorphum* (Diesing 1850). In *Euclinostomum* Travassos 1928 the intestinal branches have long lateral diverticula, sometimes ramifying. In *Ithyclinostomum* Witenberg 1926 the lateral diverticula are short and never ramifying. This genus is further separated from *Clinostomum* on the distribution of the vitelline glands. In the latter these glands extend into the anterior part of the body.

The complete life history of *C. complanatum* was only recently worked out. It was known for some time that the adult worms could be found in the oral cavity of herons (*Ardea*) and related birds (Osborn 1911, 1912). In this country Hunter and Hunter (1934, 1935) showed that when the eggs of the parasites drop from the mouth cavity of the definitive host into water, they hatch into miracidia which penetrate the liver of snails. Two gastropods, *Helisoma campanulatum* (Say) and *H. antrosum* (Conrad), were experimentally infected. In the snail each miracidium develops into a sporocyst which produces rediae. The rediae in turn produce daughter rediae which become fork-tailed cercariae. These emerge from the snail and encyst as metacercariae, commonly called yellow grubs, on fishes. When an infected fish is eaten by a bird, the larvae are released and grow to maturity in the oral cavity.

Of the several species of *Clinostomum* described from fishes, the only other forms in which the adults are definitely known are *C. heterostomum* and *C. dimorphum* from ardeiform birds, and *C. intermedialis* from the cormorant (*Phalacrorax vigua*). Without doubt, however, a life-cycle similar to that of *C. complanatum* may be expected in the entire genus.

The following are species of adult *Clinostomum*, described from various definitive hosts, of which neither the first nor the second developmental stages are known: *C. dubium* Leidy 1856, *C. detruncatum* Braun 1899, *C. foliiforme* Braun 1899, *C. heluans* Braun 1899, *C. lambitans* Braun 1899, *C. sorbens* Braun 1899, *C. hornum* Nicoll 1914, *C. australiense* Johnston

1916, *C. pusillum* Lutz 1928, *C. phalacrocoracis* Dubois 1931, and *C. lopho-phallum* Baer 1933.

Two species of *Clinostomum* have been described from amphibians. Cort (1913) believed that the *C. marginatum* reported from batrachians (Wright 1897; Osborn 1911, 1912) was a distinct species, which he called *C. attenuatum*. His separation is based principally on certain morphological characteristics. He designated the American bittern as the probable defini-tive host of the metacercariae in amphibians, but Alvey and Stunkard (1932) reported *C. attenuatum* from the great blue heron. Hunter and Hunter (1934) demonstrated in feeding experiments that the great blue heron could be infected with metacercariae taken from frogs, but that the rate of infection was not as high as with *C. marginatum* from fish. They further showed (1935 a, b) that when both sunfish and tadpoles were ex-posed to the cercariae of *C. marginatum*, the sunfish became infected while the tadpoles remained free of metacercariae. They concluded that *C. at-tenuatum* is a distinct species. The other *Clinostomum* reported in amphibia is *C. pseudoheterostomum* Tubangui 1933, which occurs in the thigh muscle of a Philippine frog (*Rana magna*). The adult of this species, however, is unknown.

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EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. *Corynopoma riisei* Gill showing the yellow grub encysted in the transparent muscle tissue. The worm appears as a dark spot behind the visceral mass.

Fig. 2. Fish shown in Fig. 1, immediately after death. The cyst was broken open and the living worm removed.

PLATE II.

Fig. 3. Female "guppy", *Lebistes reticulatus* (Peters), about 1½ inches long, showing five or more *Clinostomum* cysts. Smaller males were also found infected.

Fig. 4. *Clinostomum complanatum* (Rud. 1814) from the "guppy" shown in Fig. 3. Enlarged about 22X.

Fig. 5. *Clinostomum complanatum* from the gymnotid, *Sternopygus macrurus*. Enlarged about 22X.

FIG. 1

FIG. 2

SOME TROPICAL FISHES AS HOSTS FOR METACERCARIA OF CLINOSTOMUM
COMPLANATUM (RUD. 1814) (=C. MARGINATUM RUD. 1819).
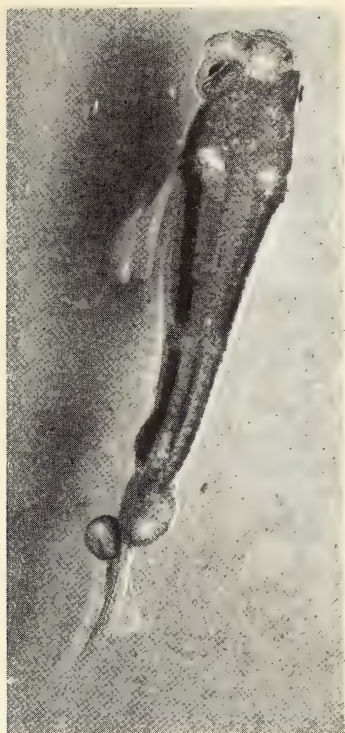
FIG. 3

FIG. 4

FIG. 5

SOME TROPICAL FISHES AS HOSTS FOR METACERCARIA OF CLINOSTOMUM
COMPLANATUM (RUD. 1814) (=C. MARGINATUM RUD. 1819).

23.

Caudal Skeleton of Bermuda Shallow Water Fishes. I. Order Isospondyli: Elopidae, Megalopidae, Albulidae, Clupeidae, Dussumieriidae, Engraulidae.[1]

GLORIA HOLLISTER.

Department of Tropical Research.

(Text-figures 1 to 53).

INTRODUCTION.

The following paper is a study of the caudal skeleton of the Bermuda isospondylids. It deals principally with the adult fish but when young specimens were available these have been included. The Isospondyli of Bermuda are represented by six families, eight genera, and eight species.

In the genus *Harengula* no specific name has been given to the material examined. These fish have at various times been called *H. macrophthalmus* or *H. sardina*, and their proper specific determination is a problem for future study.

This study was made from specimens which were cleared by potassium hydroxide and stained by alizarin. Alizarin is a vital stain for bone and the determination of the presence and position of bones is greatly facilitated by its use. The term KOH, which stands for potassium hydroxide, the clearing chemical, was adopted in our field laboratory at Nonsuch, Ber-

muda, as a designation for specimens cleared and stained. They are num-
bered as such in a KOH catalogue. This term appears in the list of cata-
logue numbers and in general usage. For details of this clearing process
see "Clearing and Dyeing Fish for Bone Study," *Zoologica*, Vol. XII, No.
10, and "Fish Magic," in the *Bulletin* of the New York Zoological Society
for March-April, 1930. (Vol. XXXIII, No. 2).

The length of specimens in this paper is standard length, unless other-
wise stated.

I am especially indebted to Mr. and Mrs. George Arents, Jr., and Mr.
and Mrs. Bernard Baruch, Jr., for specimens of large *Tarpon,* and to the
American Museum of Natural History for a specimen of *Elops.* I thank
for their cooperation Dr. William Beebe and Mr. John Tee-Van of this de-
partment. The drawings are by Edward Delano, George Swanson, and
Helen Tee-Van.

<div align="center">

CAUDAL FIN TERMINOLOGY.
(Text-figs. 1, 2).

</div>

Caudal Ray Count: The dorsal and ventral counts of fin rays are considered
separately. The dorsal count begins anteriorly and continues around
the fin to the median division in the rays. The ventral count begins
anteriorly and continues around the fin to the median division. The
count is expressed as follows:

$$\frac{\text{Dorsal}\quad \text{raylets+rays=Total:}}{\text{Ventral}\quad \text{raylets+rays=Total:}} \text{ or } \frac{2+10}{2+10} = \frac{12}{12}$$

Caudal Ray: A branched (usually) caudal element possessing one or more
transverse joints.
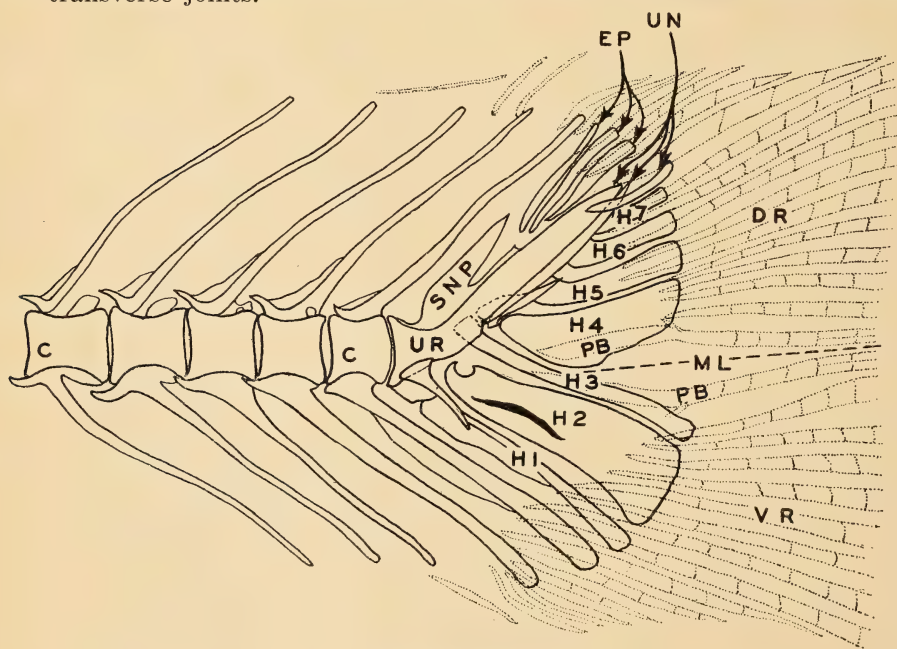
Text-figure 1.
Typical tail of a Bermuda Isospondyli. C, centrum; DR, dorsal ray; EP, epural;
H, hypural; ML, median line; PB, prolonged base; SNP, specialized neural
process; UN, uroneural; UR, urostyle; VR, ventral ray.

Caudal Raylet or *Simple Ray:* An unbranched caudal element possessing no transverse joints. Raylets are always anterior to the rays.

Caudal Region: The vertebral column is divided into a trunk and caudal region. The caudal region begins where the first or anterior haemal process forms a closed haemal arch with a single haemal spine projecting. Ribs are absent in the caudal region.
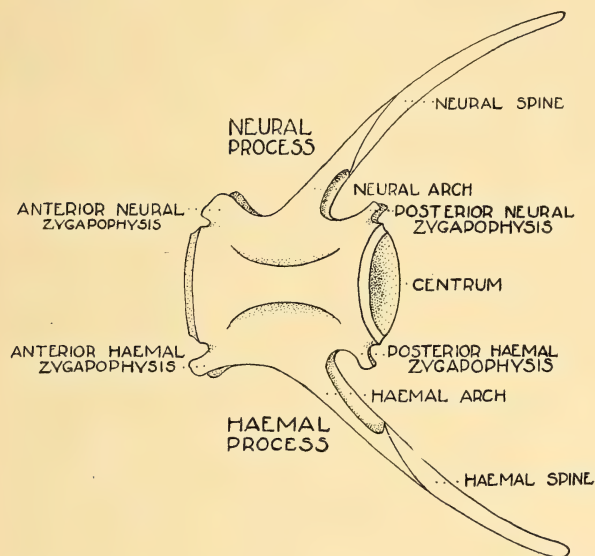
Text-figure 2.
Typical caudal vertebra.

Centrum: The central element of a vertebra on which the neural and haemal processes are formed.

Epural: Any bone, or bones, that are dorsal to the urostyle and support one or more caudal fin rays or spines. The bases are always unattached.

Haemal Arch: The arch on the ventral surface of a vertebral centrum through which passes the haemal vessel.

Haemal Process: The haemal arch and haemal spine on the ventral surface of a vertebral centrum.

Haemal Spine: The ventral projection below the haemal arch.

Hypural: Any bone that is ventral or posterior to the urostyle and supports one or more caudal fin rays or raylets. An expanded haemal spine. The hypural count is made from the anterior ventral part of the urostyle around to its posterior and dorsal end. The anterior hypural is called the first hypural.

Median Caudal Line: The median line is the natural median division seen in the caudal rays. This line determines whether the rays are dorsal or ventral.

Neural Arch: The arch on the dorsal surface of a vertebral centrum through which passes the nerve cord.

Neural Process: The neural arch and the neural spine on the dorsal surface of a vertebral centrum.

Neural Spine: The dorsal projection above the neural arch.

Uroneurals: The uroneurals are paired bones which are directed upward and backward on the lateral and dorsal surfaces of the urostyle. They probably represent specialized neural processes so developed to protect the sharply upturned caudal. This term is adopted from Regan (1910. 2).

Urostyle: The posterior terminal vertebral segment or segments which follow the last undoubted centrum. The urostyle is considered as one in the total vertebral count.

Zygapophysis: The dorsal and ventral articulating process of a centrum.

The inserted key illustrates the outstanding differences and similarities found in the study of the caudal skeleton of the Bermuda isospondylids. It will be noted that the three clupeids (*Harengula, Opisthonema,* and *Sardinella*) are included under one caudal pattern. Further study with more material is necessary in these species to determine the status of the three forms as shown by the caudal skeleton.

ELOPIDAE.
Elops saurus Linnaeus.
(Text-figs. 14, 15).

Diagnostic Characters:

> 9 hypurals.
> 2 reduced posterior neural processes on the two anterior urostyle centra. Dagger-shaped.
> 4 distinct pairs of uroneurals. Origin of anterior pair on first or anterior urostyle centrum.

Vertebral count:

> 49 + 26 = 75.   Haiti specimen.
> 57 + 24 = 81.   Gravesend Bay, N. Y., specimen.
> 43 + 29 = 72.   Jordan and Evermann, "Fishes of North America."
> 78-79. *Elops saurus* and *affinis.* Regan 1909.

This variation may, with further study, be correlated with geographical distribution.

Material Studied.

The following description is taken from two specimens: one caught in Haiti, Cat. No. 7172, KOH Cat. No. 2030, length 258 mm., from which this description has been made, and one caught at Gravesend Bay, which was kindly supplied by the American Museum of Natural History, Cat. No. 669, KOH Cat. No. 2136, length 280 mm. *Elops saurus* is included with the group of Bermuda Isospondyli on the basis of a single record, that of E. Linton in 1908, "Notes on Parasites of Bermuda Fishes," Proc. U. S. Nat. Mus., XXXIII, No. 1560.

Caudal Osteology.

Urostyle Centra: Four centra form the upturned caudal end of the vertebral column. The anterior three are regularly shaped. The fourth (and posterior) one is an irregular thin bony rod which curves upward posteriorly and extends as far as the anterior dorsal edge of the 7th hypural. This may represent three centra fused as it extends over the bases of three hypurals. A cartilaginous notochord extends into the dorsal contour, 1 mm. beyond the dorsalmost hypural, and is embedded between the bases of the 11th dorsal ray, above the median line (Text-fig. 15). There are about 35 horizontal striae in the cartilaginous notochord. Embedded between the striae spool-shaped centra can be seen. This condition resembles that found in the young rather than the adult *Tarpon.*

Uroneurals: This term is adopted from Regan (1910.2). There are four pairs of uroneurals, which correspond to ancestral posterior neural

Key to Caudal Fin of Bermuda Shallow Water Isospondylid Fishes.
(Text-figs. 3-13).

1.

Group A
   25 to 26 haemal arches.
   (Total vertebral count 37 to 40).

Harengula sp.
(See Text-figs. 47 and 48).

Group B
   29 to 32 haemal arches.
   (Total vertebral count 45 to 46).

Text-figure 12.

Opisthonema oglinum
(See Text-figs. 49, 50 and 51).

Sardinella anchovia
(See Text-figs. 52 and 53).

Text-figure 13.

ISOSPONDYLI

Group I

9 hypurals;
4 pair of uroneurals.

ELOPIDAE
Elops saurus

Text-figure 3.
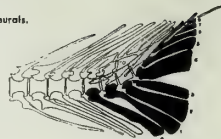
Group II

8 hypurals;
3 pair of uroneurals.

MEGALOPIDAE
Tarpon atlanticus

Text-figure 4.
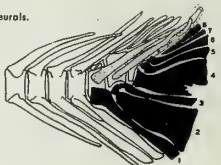
Sub-Group A

Massive neural and haemal spines on the 4 posterior vertebrae; no prolonged ray bases of the 2 median caudal rays.
2 pair of uroneurals.

ALBULIDAE
Albula vulpes

Text-figure 5.
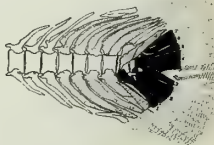
Group III

7 hypurals;

Sub-Group B

Slender neural and haemal spines on the 4 posterior vertebrae; prolonged ray bases of the 2 median caudal rays.

Text-figure 6.
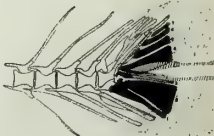
Division I

1 epural.
Caudal rays 26, (14/12).

Text-figure 7.

DUSSUMIERIIDAE
Jenkinsia lamprotaenia
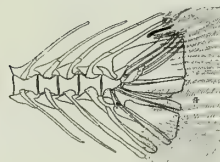
Text-figure 11.

Division II

More than 1 epural; 2, 2½, or 3.
Caudal rays 33 to 37.

Text-figure 8.

Text-figure 9.

Text-figure 10.

Sub-Division A

ENGRAULIDAE
Anchoviella choerostoma

Long neural process of urostyle extending dorsally at least one half the length of the anterior epural.
First closed haemal arch above anterior spine of anal fin.
Caudal and trunk vertebrae almost evenly divided.
Caudal rays 33 to 37, 17/16 to 19/18, never 19/16 as in Sub-Division B, Clupeidae.
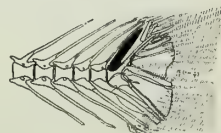
Text-figure 12.

Sub-Division B

CLUPEIDAE

Short neural process of urostyle extending to the ventral tip, or slightly beyond, of the anterior epural.
First closed haemal arch well in advance of the anal fin.
More caudal vertebrae than trunk.
Caudal rays 35, 19/16.
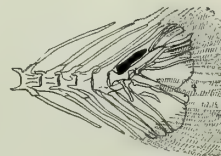
Text-figure 13.

Group A

25 to 26 haemal arches.
(Total vertebral count 37 to 40).

Harengula sp.
(See Text-figs. 47 and 48).

Group B

29 to 32 haemal arches.
(Total vertebral count 45 to 46).

Opisthonema oglinum
(See Text-figs. 49, 50 and 51).

Sardinella anchovia
(See Text-figs. 52 and 53).

processes. All four are elongated and crowded together on the lateral and dorsal surfaces of the upturned centra.

The uroneural whose position is the most anterior and the most dorsal is the longest (16 mm.) and the stoutest (1.5 mm. at the deepest point) and extends from the first upturned centrum as far as the center of the anterior base of the 9th (dorsalmost) hypural. Here it terminates in a blunt tip. Anteriorly this uroneural is forked, the dorsal part commencing on the first urostyle centrum which is the fourth from the last. According to Regan (1910.1) "the forking indicates the compound nature of this bone,
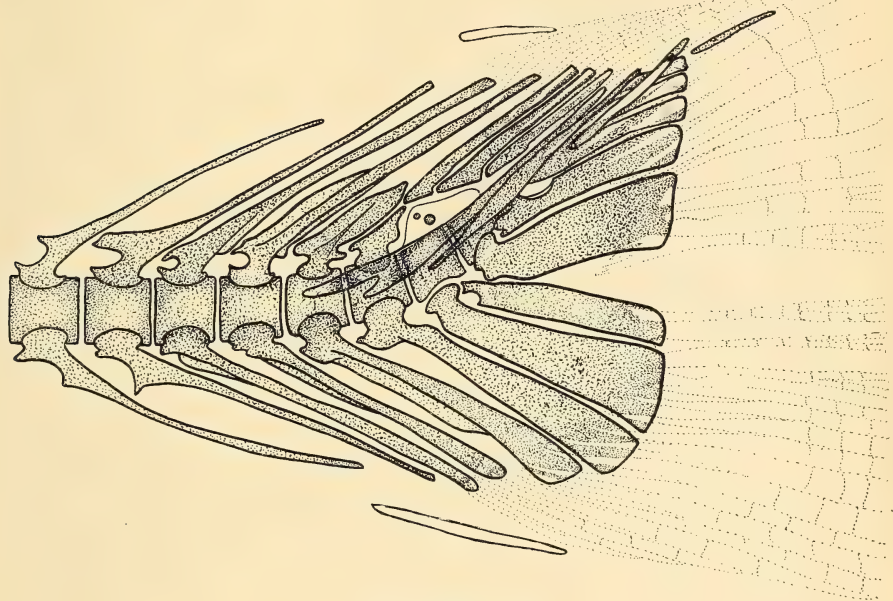
Text-figure 14.
Elops saurus. Tail of a 258 mm. specimen (x 2.8).

and in some specimens the line of junction between the two component elements can be clearly seen." In our Haiti specimen of 258 mm. and Gravesend Bay specimen of 280 mm., the line of junction is not evident. The anterior pair of uroneurals is the only one that covers in part the dorsal, as well as the lateral surfaces of the urostyle. The anterior half is entirely lateral but above the posterior, or last, centrum the lateral parts meet dorsally, but do not fuse, and extend for a short distance covering both the dorsal and upper lateral surfaces of the urostyle.

The bones of the second pair of uroneurals are spindle-shaped, 12.5 mm. long and 1 mm. deep, unforked and extend along the ventral surfaces of the first pair. The second pair arises anteriorly on the third centrum and ends between the bases of the 11th caudal ray, extending 2 mm. beyond the first pair.

The third pair resembles the second in shape but the bones are one-half the size. The length is 6.43 mm. and the depth .43 mm. This pair arises at the posterior third of the second pair and extends slightly beyond it, ending posteriorly between the bases of the 11th ray.

The fourth pair is the smallest, length 3.86 mm. and depth .29 mm. The bones extend obliquely across the 10th dorsal ray with the anterior tips

on the dorsal side and the posterior on the ventral side of the ray. The direction does not parallel that of the other three pairs; instead there is a decided posterior slant. The entire length of the two bones is free in the tissue that covers the ray bases; whereas the dorsal tips of the other three uroneurals are between the bases of the 11th caudal ray.

None of these pairs are fused one with the other. The two bones of each pair are distinctly individual.

Hypurals: There are nine hypurals on the urostyle, four below and five above the median line. Two additional anterior long haemal spines project into the ventral caudal contour with fin rays attached. The third hypural (counting from the anterior to the posterior dorsal) is the largest.
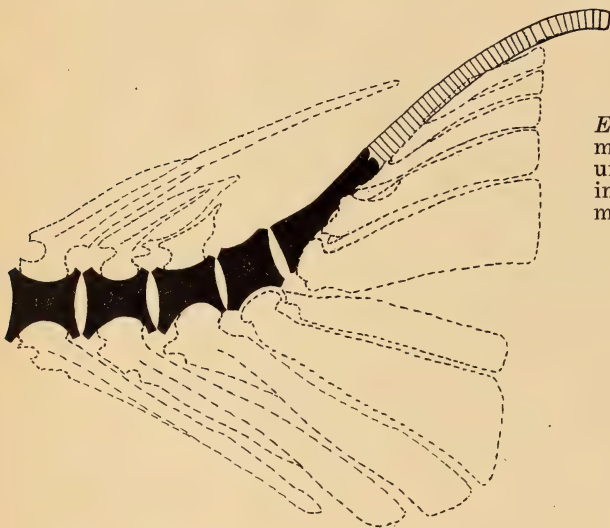
Text-figure 15.

Elops saurus. Tail of 258 mm. specimen with paired uroneurals removed showing, in black, the vertebral segments of the urostyle (x 3).

The ninth and dorsalmost hypural is the smallest. The bases of the third and fourth hypurals are ventral and adjacent to a single centrum. This is also shown in Regan's drawing (1910.1) and is present in *Tarpon* and *Albula* and indicated in all the Bermuda isospondylids. None of the hypurals are fused. All of the bases are cup-shaped and the two dorsal ones are more pronounced, almost bifid, the basal tips extending on either side of the notochord. The Haiti specimen is more developed in this respect, the bases being noticeably longer. (Text-fig. 17 for example in *Tarpon*).

Epurals: There are three epurals, all long flat bones expanded at the ventral ends. The first and anterior epural is the longest, its ventral end slightly over-lapping the tip of the anterior reduced neural process.

Specialized Neural Processes: There are two reduced neural processes on the first and second upturned urostyle centra. Both are short, broad, dagger-shaped bones, the anterior one being the larger. The anterior neural process is on the first centrum that shows a tendency to turn upward. So this centrum is considered the first of the urostyle series and the attached haemal spine is called the first hypural in this paper.

The shape of the neural processes of the Gravesend Bay specimen is different from the Haiti specimen, the tips being blunt and the same depth as the rest of the process. There is a third smaller process, which is not present in the Haiti specimen. This may be an individual irregularity and not a common variation. But as there are only two specimens from which to draw conclusions this point will be left open to be determined later. This study is too new to base specific differences on characters such as the

neural processes without more specimens to establish the normal range of variation.

Dorsal to the third urostyle centrum are two small round islands of bone surrounded by a median plate of cartilage. In Regan's illustration a solid bone is shown filling this entire area below the three epurals. The Gravesend Bay specimen has one round island of bone which is of interest because of the smaller size of the fish. Regan's specimen is undoubtedly older than both of ours, although no length is given. In certain fishes of other families where a series of specimens is available for study, ranging in development from young to adult, this particular area is one of the last to ossify. Our adult six-foot *Tarpon* is a striking example.

Caudal Fin Ray Count:

258 mm. $\frac{2 + 16 = 18}{1 + 15 = 16}$ Haiti specimen. There are two dorsal and one ventral anterior raylets which lack the characteristic cross bars of the rays.

280 mm. $\frac{2 + 17 = 19}{1 + 15 = 16}$ Gravesend Bay specimen.

Specialized Ray-scales: Partly covering the first dorsal and ventral raylets there is a thick elongate bony ray-scale. This was present in *Leptolepidae,* and of the Bermuda isospondylids, is seen in a more reduced size in *Tarpon, Albula,* and most of the clupeids.

MEGALOPIDAE.
Tarpon atlanticus (Cuvier & Valenciennes).
(Text-figs. 16-20).

Diagnostic Characters:

8 hypurals.

Small pointed reduced neural process on the anterior part of the first urostyle centrum.

3 distinct pairs of uroneurals.

Vertebral count: 33 + 24 = 57.

In the closely related Pacific and Indian Ocean *Megalops cyprinoides,* the vertebral count is 38 + 30 = 68. (Delsman, 1926).

Material Studied.

The following description is from one adult fish, weight one hundred pounds, length six feet, or 1,800 mm. (Text-figs. 16, 17, 18). This specimen was taken in Florida, the gift of Mr. and Mrs. George Arents, Jr., KOH Cat. No. 2085. Any differences in younger stages are mentioned, being described from a two-foot fish, 635 mm., caught in Florida, the gift of Mr. and Mrs. Bernard Baruch, Jr., KOH Cat. No. 2083, and from three specimens, (Text-figs. 19, 20), taken in Haiti, Cat. No. 7303, KOH Cat. Nos. 2031 and 2033, lengths 140, 120, 115 mm. At the time of writing (October, 1936), the 115 mm. specimen is the smallest *Tarpon* available for study in the collection of the Department of Tropical Research and in all other institutions with which I communicated. The two-foot specimen is essentially like the six-foot fish and the drawing for the latter represents both stages and all those in between.

In Bermuda *Tarpon* are rare. A single skin was seen by G. Brown Goode, (Catalogue of the Fishes of the Bermudas, 1876), in the collection of John T. Bartram of St. George. We have seen *Tarpon* only occasionally while helmet-diving.

Caudal Osteology.

Urostyle Centra: In the six-foot fish two complete centra, one elongate centrum and an additional reduced terminal centrum, form the urostyle. The elongate element extends from the fourth hypural to the tip of the seventh. This is heavier and larger than in the younger specimens. It is
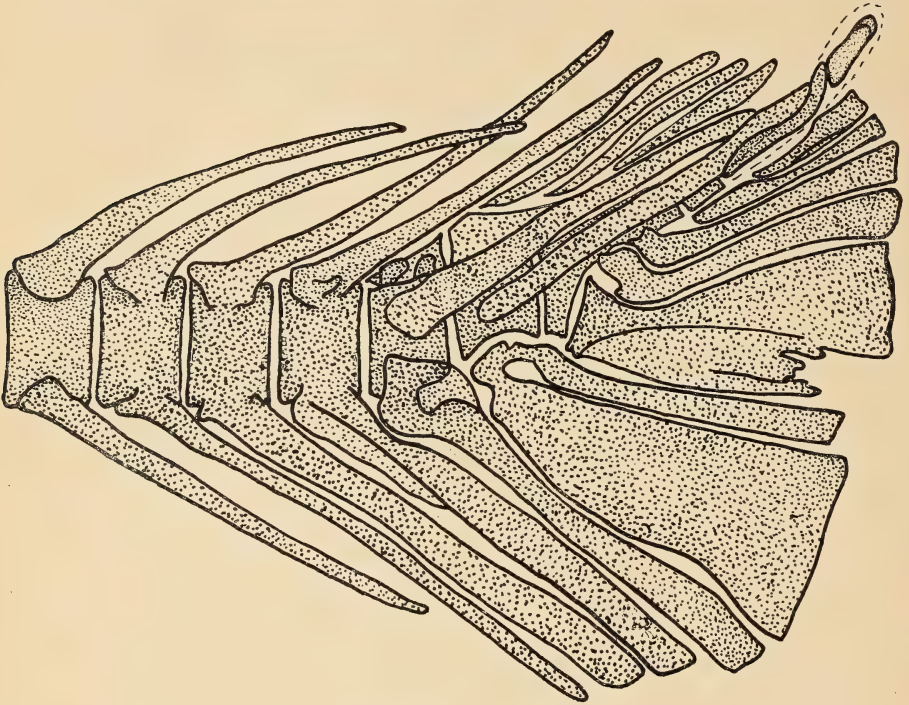
Text-figure 16.
Tarpon atlanticus. Tail of 1,800 mm. specimen (x 4/5).

irregularly shaped throughout and in the center of its length on the ventral side it resembles a thin keel which lies between the pseudoarches of the fifth and sixth hypurals. The terminal bony segment, which is not present in the smaller specimens, extends three-fourths of the length of the base of the seventh hypural. It is open above but complete below and the ossification is thin and delicate (Text-fig. 16). The notochord is seen extending from this last ossified segment into the caudal contour 10 mm. beyond the dorsal, or eighth hypural. Its end is embedded in the eleventh dorsal ray above the median line. Enclosed in a tough fibrous sheath are 18 or more separate irregular vertebral elements. All are slightly ossified. The ossification of the tip end which extends beyond the hypurals is heavier on the edges and the tip than in the center. Ventrally, this seems to be solid but dorsally it appears cleft and may be two lateral plates in close proximity (Text-fig. 18).

In the smallest specimens (Text-fig. 19), two complete centra and one elongate terminal centrum form the urostyle. This posterior rod-like centrum shows definite indication of fusion of two centra. As it extends over three hypurals, the fourth, fifth, and sixth, similar to *Elops*, it may be a composite of three centra. The cartilaginous notochord prolongation from this last centrum, very similar to that of *Elops*, extends from the base of

the sixth hypural into the dorsal caudal contour, 3 mm. beyond the eighth hypural (Text-fig. 20). As in *Elops,* it is embedded in the base of the 11th dorsal ray, above the median line.

Uroneurals: There are three pairs of uroneurals, which correspond to ancestral posterior neural processes. All three are elongated bones and are close together on the dorsal and lateral surfaces of the upturned uro-

Text-figure 17.
Tarpon atlanticus. The eighth hypural showing the bifid, arch-like base in three-quarter view (x 1).

style, covering the three centra and the cartilaginous notochord, all except the extreme tip which extends beyond the hypurals. None of these pairs is fused one with the other and the two elements of each pair remain distinct.

The first uroneural, anterior and dorsalmost in position, is the longest (67 mm.) and the widest (8 mm.) at the deepest part, which is the anterior end. (The measurements of the small specimens are 11 mm. by .8 mm. wide). The bones of this pair extend from the anterior edge of the first centrum of the urostyle, above, but on a vertical line with the center of the dorsal side of the 8th hypural. They end in tapering pointed tips. The an-
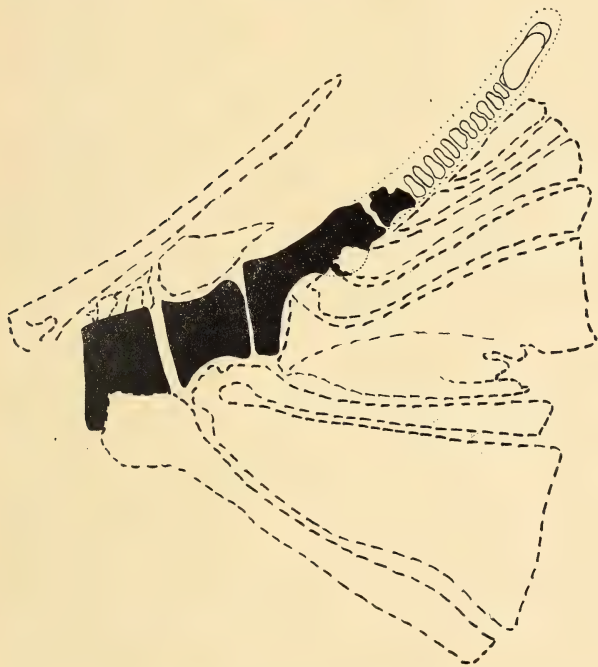
Text-figure 18.
Tarpon atlanticus. Tail of 1,800 mm. specimen with paired uroneurals removed showing, in black, the ossified vertebral segments (x 4/5).

terior is rounded and unforked and differs in this respect from *Elops.* This is the only pair to cover in part the dorsal as well as the lateral surfaces of the urostyle. The anterior half is entirely lateral and above the third urostyle centrum the two lateral bones meet dorsally, but do not fuse.

The bones of the second pair of uroneurals are spindle-shaped with rounded anterior ends. This differs from the three small specimens of 115,

120, and 140 mm. as the illustration shows (Text-figs. 16, 19). The length of the uroneurals is 61 mm. and the width at the widest part in the center, is 6 mm. They arise one-fourth of the distance from the anterior edge of the second centrum of the urostyle and extend ventral and parallel to the first pair. Distally they end between the bases of the 10th and 11th caudal rays, above the median line, and extend 8 mm. beyond the first pair. (The measurements of the three small specimens are 9.2 mm. by .4 mm. wide).

The third pair of uroneurals is very small, the left bone being longer and more slender than the right and less closely associated with the underlying uroneurals. The length of the left bone is 25 mm. and the width 3 mm. It arises, approximately, at the posterior third of the second pair above the tip of the 8th hypural. The bones extend across the tips of the 2nd uroneurals, bending obliquely upward and projecting across the notochord beyond the epurals. (The measurements of the small specimens are 3 mm. by .1 mm.).

Hypurals: There are eight hypurals on the urostyle, three below and five above the median line. Three additional long haemal spines project into the caudal contour with fin rays attached. As in *Elops* there are two
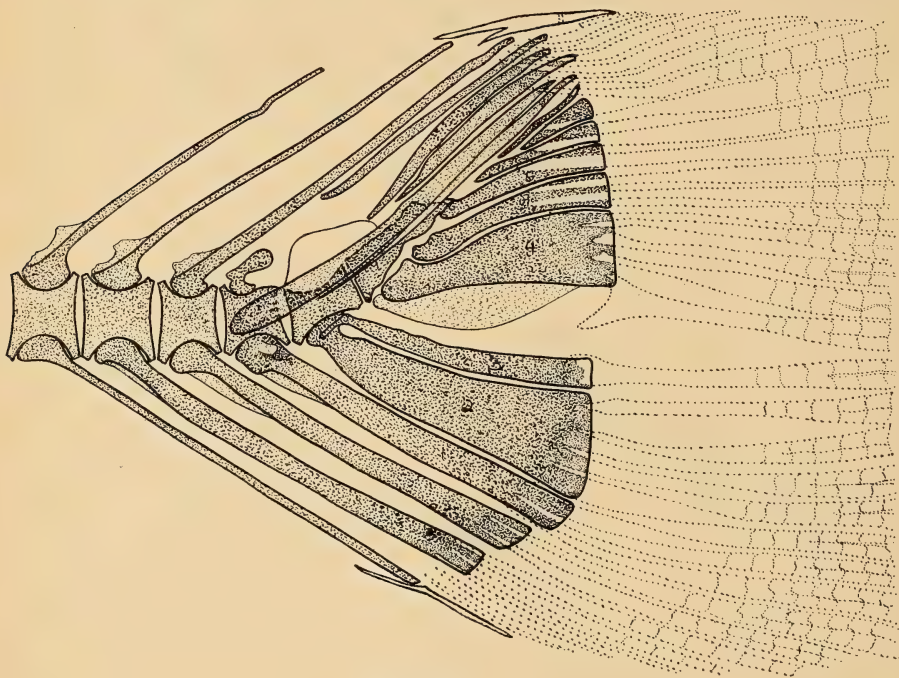
Text-figure 19.
Tarpon atlanticus. Tail of 150 mm. specimen (x 4.75).

hypurals ventral and adjacent to a single centrum, the second. In *Tarpon* the basal ends of the two hypurals are closely associated in the small fish and appear as one in the two-foot and six-foot specimens. In our *Elops* the basal ends are distinct. The association of two hypurals with the 2nd centrum is also present in *Albula vulpes* where in the adult they are in close proximity to each other and the centrum. In all of the Bermuda Isospondyli, other than *Elops, Tarpon,* and *Albula,* the larger and ventral bone of the two below the 2nd centrum is entirely free from the centrum but the smaller and dorsal bone has become united with it.

All of the hypurals remain unfused and separate for their entire length. As in many specimens of other families, there is a noticeable band of cartilage on the extremity of all of the hypurals and in the big *Tarpon* there is a trace, here and there, of ossification on the outer edge of this band. As in *Elops*, the bases of the hypurals are cup-shaped and bifid (Text-fig. 17).
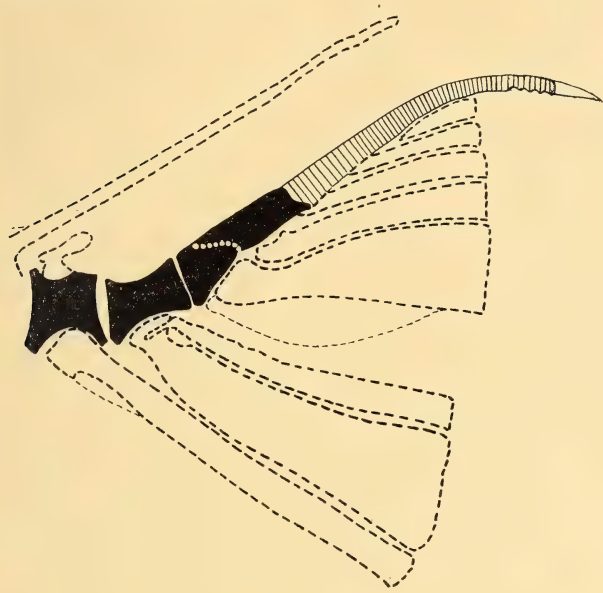
Text-figure 20.

Tarpon atlanticus. Tail of 140 mm. specimen with paired uroneurals removed showing, in black, the ossified vertebral segments of the urostyle (x 5.5).

Epurals: There are three epurals which are all long and rod-like. They differ slightly in shape and length, the anterior epural being the longest and the most slender and the posterior two being the shortest and the stoutest.

In the three small specimens there is an unossified area between the ventral tips of the epurals and the urostyle centra. There is a plate of cartilage here which, in both the two-foot and six-foot specimens, is ossified. In *Elops* this area is considerable smaller, being partly filled by the overlapping of the reduced neural processes and the tips of the epurals. In *Elops* a cartilage plate is present with two small round ossified islands in the larger and one center of ossification in the smaller.

Specialized Neural Processes: In the three small fishes there is one reduced neural process which is located on the first upturned urostyle centrum. This is a rounded hook-shaped bone which curves abruptly toward the posterior. In the six-foot specimen this hook-shaped reduced neural arch is present but in addition there is a second smaller one arising on the same centrum and both are united by and appear embedded in a median bony plate filling the area above this centrum. Possibly this is an individual irregularity or malformation during growth of this particular specimen.

Caudal Fin Ray Count:

$$1{,}800 \text{ mm. fish.} \quad \frac{16}{13}$$

$$635 \text{ mm. fish.} \quad \frac{17}{14}$$

$$140, 120, 115 \text{ mm.} \quad \frac{3 + 13 = 16}{1 \text{ or } 2 + 13 = 14 \text{ or } 15}$$

Specialized Ray-scales: Without the study of cleared and alizarin stained specimens, the single dorsal and ventral ray-scale would be counted as caudal rays, so perfectly do their extremities form part of the series of graduated caudal raylets. But in the cleared specimens the bases are seen to be quite unlike the rays in shape, origin, and position and resemble more the structure of the ray-scales found in *Elops* and *Albula,* and some of the clupeids, than that of raylets. Regan (1910.1) made the following note: "In *Elops,* but not in *Megalops,* there is an oblong ray-scale above and below, partly covering the first upper and lower rays."

ALBULIDAE.

Albula vulpes (Linnaeus).

(Text-figs. 21-39).

Diagnostic Characters:

7 hypurals.

No reduced neural processes as in *Elops* and *Tarpon.*

2 distinct pairs of uroneurals in the largest adult.

4 distinct pairs in the smallest adults of 47, 40 and 36 mm.

Vertebral count in large adults:

42 + 27 = 69. Bermuda specimens.

42 + 28 = 70. Jordan and Evermann, "Fishes of North America."

47 + 27 = 74. Delsman, Java Sea specimens.

Material Studied.

	Group	Length	Cat. No.	KOH Cat. No.	Text-fig.No.
		560 mm.		1134	21, 29
	A	510 mm.		1084	21, 29
		403 mm.		815	21
		206 mm.	9647	670	21, 28
10 Adults, ranging from 560 to 22 mm.	B	87 mm.	25184	768	29
		84 mm.	25183	767	25, 26
		47 mm.	25181	2057	22, 23, 24
	C	40 mm.	25182	2060	22, 23, 24
		36 mm.	25185	2081	22, 23, 24
	D	22 mm.	25208	2120	34
1 Intermediate		26 mm.	25209	2119	33
Leptocephalus .... (3 out of 15)		30.8 mm		2115	32
		45 mm.		2080	31
		55 mm.		147	30

This paper dealing with isospondyls is concerned more particularly with adult specimens. *Albula* is an exception in its series of fish which range in size from young to adult. The following does not aim to be a complete description of the leptocephalus phase but rather a summary of the outstanding changes occurring in the different growth stages. During seven seasons of work in Bermuda specimens of the above range in lengths were collected and studied. The figure at the top of the column represents the largest and oldest and the last figure, 55 mm., the youngest. It will be seen by reading the column from the bottom to the top that the young in growing first decrease in length; at the same time they change from ribbon-like creatures to the shape of the adult. Then growth continues by lengthening.

Although specimens have been had in collections which show *Albula*

in both phases, it has not been known just when the change occurs and the rapidity of this change. I definitely established these facts by observations on a living *Albula* which grew and shrank from 55 mm. to 20 mm. in ten days' time. During this time it changed from the leptocephalus to the adult in body shape.[2]

Caudal Osteology.

Urostyle Centra: The fully adult urostyle (560, 510, 403 and 206 mm.) is composed of two complete centra, the posterior one being greatly reduced in size (Text-figs. 21, 29). Almost completely hidden under the uroneurals is a posterior terminal bony mass which probably represents several fused centra (Text-fig. 28). In the three small specimens of 47, 40, and 36 mm., four centra can be distinguished (Text-figs. 22, 23, 24). The two posterior ones are rod-shaped and very close together. The posterior terminal bone
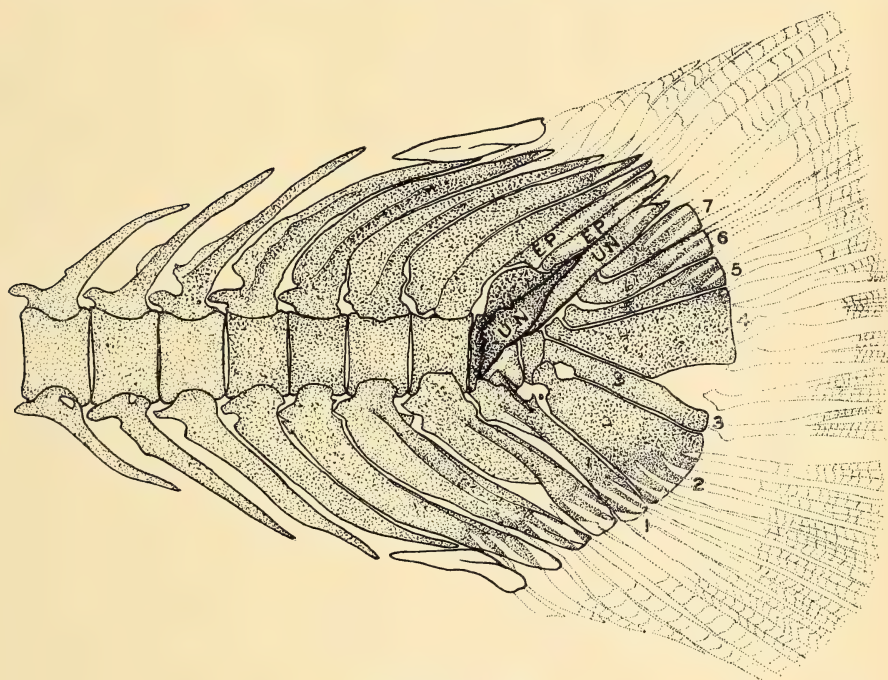
Text-figure 21.
Albula vulpes. Tail of 560 mm. specimen (x 1.4).

is above the center of the base of the sixth hypural (third above the median line). In the 87 and 84 mm. specimens there are only three centra, the posterior two having fused (Text-figs. 25, 26, 27).

In dissecting the 206 mm. specimen (Text-fig. 28) the second urostyle centrum was found noticeably reduced and the fourth hypural elongated with its base in the position of the third centrum as seen in the 84 mm. specimen (Text-figs. 25, 26). The terminal fused centrum is pushed out of its youthful position, where it formed the upward curve in the urostyle, and its anterior basal end is almost superimposed on the second urostyle centrum. The notochord is seen extending posteriorly as in smaller speci-

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[2] See *Bulletin*, New York Zoological Society, May-June 1936, Vol. XXXIX, No. 3.

mens. Anterior to the base is a minute reduced bony element which looks like a miniature arch base. This is median in position, lying between the sides of the specialized neural process of the urostyle.

In the two largest specimens (560 and 510 mm.), no cartilaginous notochordal prolongation can be found after dissecting away the heavy uroneurals. But in all others, including the 206 mm. specimen, a delicate
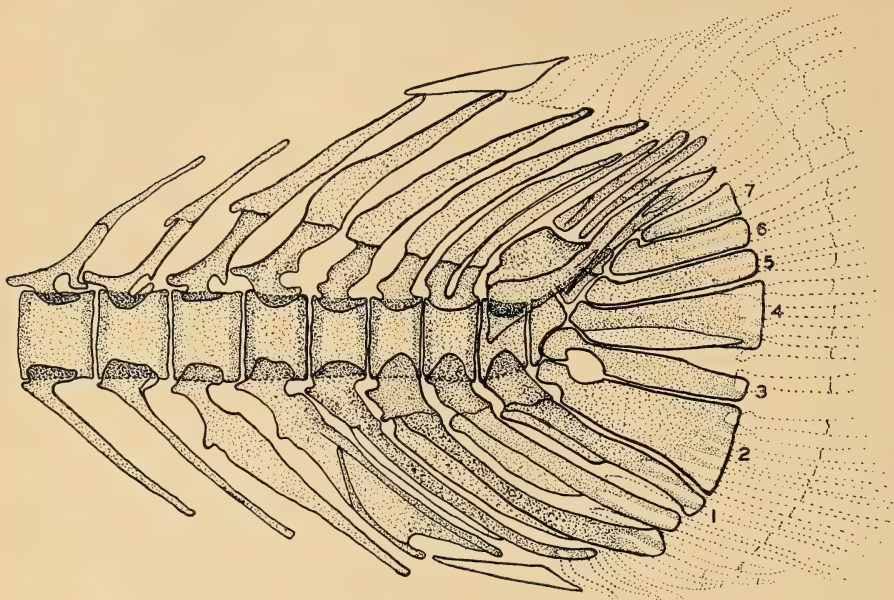
Text-figure 22.
Albula vulpes. Tail representing 47, 40 and 36 mm. specimens (x 15.5).

notochord extends, within the uroneurals, into the caudal contour, ending between the bases of the eleventh caudal ray above the median line. The notochord extends to below the tip of the sixth dorsal raylet, counting from the anterior (Text-fig. 28).

Uroneurals: In the four largest specimens (560, 510, 403, and 206 mm.) there are two pairs of heavy uroneurals which overlap each other (Text-figs. 21, 29). The irregular forward edge of the anterior pair can be traced very plainly, as it covers the greater part of the first urostyle centrum. Ventrally, its long slender tip meets the dorsal edge of the corresponding hypural. This anterior pair extends dorsally and posteriorly to about mid-length of the seventh hypural, which is the dorsalmost of the series. The posterior half is completely covered by the second pair of uroneurals, whose origin is in the center of the second urostyle centrum, dorsal to the second and third hypurals. This pair extends almost to the extremity of the seventh hypural.

In the smallest specimens (47, 40, and 36 mm.), there are four pairs of uroneurals (Text-figs. 23, 24). The two pairs which correspond to those of the adult elongate anteriorly with growth (Text-figs. 23, 29). In comparison with the 45 mm. leptocephalids (Text-figs. 36, 37), these bones have almost doubled in length, and overlap each other. In the leptocephalids only the distal and proximal ends meet. The uroneurals appear stained in the 30.8 mm. leptocephalus. In 84, 47, and 40 mm. specimens the anterior tips of the first uroneural is on the third urostyle centrum (Text-figs. 23, 25).

In the 87 mm. and all larger specimens it is on the second urostyle centrum (Text-figs. 27, 29). There is a third pair seen only in leptocephalus stages and 87, 84, 47, 40, 36 and 22 mm. specimens. In the leptocephalus this pair is the most dorsal and posterior (Text-fig. 36). These uroneurals do not elongate with growth and remain identical in length from the leptocephalus to the 87 mm. stage and become fused in the center of the first uroneural. In specimens of 206 mm. and over, there is no trace of this third pair (Text-fig. 29). A fourth pair is seen in the 47, 40, and 36 mm. specimens, extending in a dorsal direction posteriorly from the reduced neural process. This is not to be found in the largest or fully adult specimen (Text-fig. 24).

Hypurals: There are seven hypurals ventral and posterior to the urostyle, three below and four above the median line. Four additional haemal spines project into the caudal contour. The anterior one has above it the specialized ray-scale, and the three others have fin-rays attached (Text-fig. 21).

As in *Elops* and *Tarpon* the two hypurals immediately ventral to the median line arise from what appears to be a single centrum. In all other Bermuda adult Isospondyli the larger hypural of the two is well separated from any centrum attachment and is one of the largest hypurals. It resembles an isolated triangular island of bone. In the very young stages of several of the clupeids there is to be seen this same attachment to a
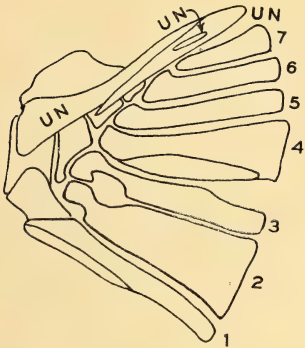
Text-figure 23.

Albula vulpes. Tail of 47, 40 and 36 mm. specimens showing the position of the three pairs of uroneurals in relation to the urostyle segments and hypurals (x 20).
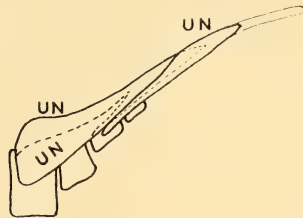
Text-figure 24.

Albula vulpes. Dissection of Text-fig. 23 showing four urostyle segments and a fourth pair of uroneurals which are dotted and lettered, being under the anterior uroneurals. The smallest pair of uroneurals has been omitted in order to show the extent of the underlying tips of the anterior uroneurals (x 20).

single centrum as in *Elops, Tarpon,* and *Albula* (Text-figs. 14, 16, 21). The bases of the hypurals are bifid as in *Elops* and *Tarpon* (Text-fig. 17, *Tarpon*).

Epurals: In the adult there are two epurals which are heavy irregular bones and in such close proximity that their respective outlines are difficult to trace (Text-fig. 21). In the young of 47, 40, and 36 mm. the two epurals are distinct (Text-fig. 22). The area above the urostyle in the young and adult is almost completely filled with the uroneurals and the specialized neural process. It is interesting to note here that in the longest and consequently the youngest of the leptocephali, where there is no evidence of
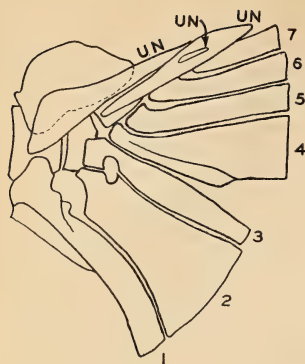
Text-figure 25.

Albula vulpes. Tail of 84 mm. specimen showing the positions of the three pairs of uroneurals in relation to the urostyle segments and hypurals. The large pairs have lengthened with growth but the small pair has remained the same (x 9).

Text-figure 26.

Albula vulpes. Dissected tail of 84 mm. specimen showing three urostyle segments instead of four as seen in the younger stages (x 7.8).
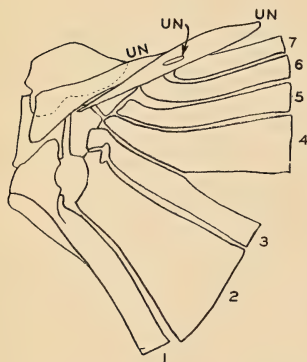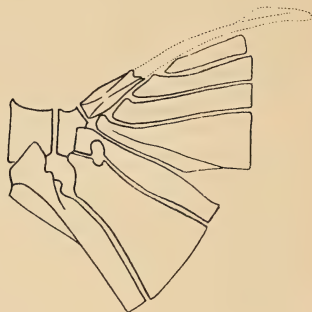
Text-figure 27.

Albula vulpes. Tail of 87 mm. specimens showing the positions of the three pairs of uroneurals in relation to the urostyle segments and hypurals. The bones of the dorsalmost uroneural have lengthened and the anterior tips are on the second urostyle segment instead of the third as in smaller specimens. The length of the small pair has remained unchanged (x 8).

Text-figure 28.

Albula vulpes. Dissected tail of 206 mm. specimen showing the more consolidated urostyle and remains of the fourth uroneurals of Text-fig. 24 (x 2.5).
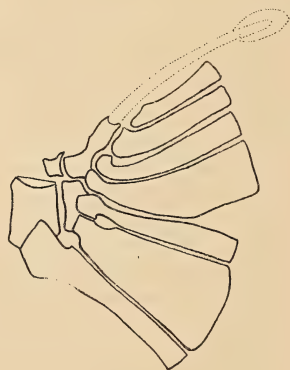
segmentation in the notochord nor absorption of alizarin, the basal ends of the two epurals are united (Text-fig. 36).

Specialized Neural Process: There is one reduced neural process on the first centrum of the urostyle (Text-fig. 21). This is ossified and de-

veloped in the 36 mm. young-adults but cannot be detected, even in cartilage form, in any of the younger specimens (Text-figs. 22, 36).

Caudal Fin Ray Count:

55 mm.	$\dfrac{11}{11}$	Leptocephalus. Caudal rays unstained (Text-fig. 36).
45 mm.	$\dfrac{11}{11}$	
30 mm.	$\dfrac{2 + 10 = 12}{2 + 10 = 12}$	Caudal rays stained.
26 mm.	$\dfrac{3 + 10 = 13}{2 + 10 = 12}$	
22 mm.	$\dfrac{4 + 10 = 14}{4 + 10 = 14}$	No trace of dorsal or ventral caudal ray-scale or body scales. (Text-fig. 37).
36 mm. 40 mm. 47 mm.	$\dfrac{6 + 12 = 18}{3 + 13 = 16}$	Caudal ray-scale present. Body scales present. (Text-fig. 22).
84 mm.	$\dfrac{3 + 15 = 18}{2 + 14 = 16}$	
87 mm.	$\dfrac{3 + 15 = 18}{1 + 15 = 16}$	
206 mm. 403 mm. 510 mm.	$\dfrac{1 + 17 = 18}{1 + 15 = 16}$	(Text-fig. 21).
560 mm.	$\dfrac{18}{16}$	(Text-fig. 21).

Specialized Ray-scales: As in *Elops* and *Tarpon*, a thick, elongate, bony ray-scale partly covers the first dorsal and ventral anterior raylet. In *Albula* this structure is heavier than in any of the other isospondylids (Text-figs. 21, 22). It is well developed in all specimens 36 mm. and longer
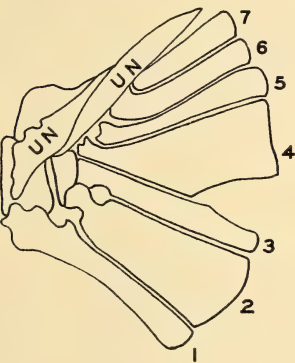
Text-figure 29.

Albula vulpes. Tail of largest adult showing uroneurals and segments of the urostyle reduced to two elements respectively (x 1.5).

but not evident, even in cartilage form, in any of the younger stages or leptocephalids.

Additional Characters Worthy of Note: All of the posterior neural and haemal spines are very heavy and thick and by this character alone adult *Albula* can be identified and distinguished from all other Bermuda isospondylids (Text-fig. 21). It is interesting to note that in several specimens there is a double neural spine structure (Text-figs. 21, 22). This

Text-figure 30.
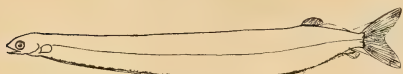
Text-figure 31.

Text-figure 32.
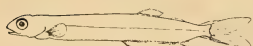
Text-figure 33.

Text-figure 34.
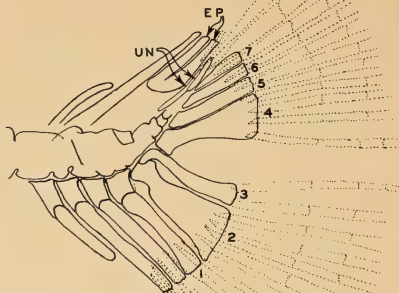
Text-figure 35.

Text-figure 36.
(x 19).
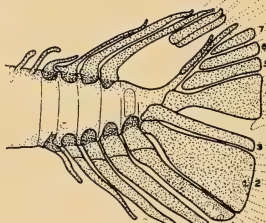
Text-figure 37.
(x 14.5).
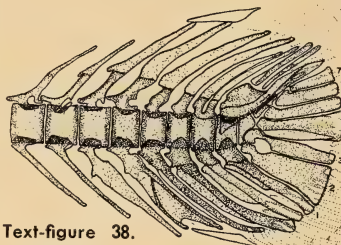
Text-figure 38.
(x 7).
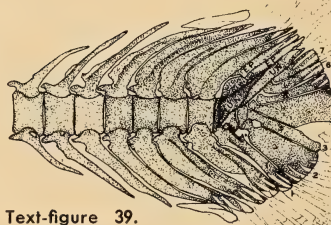
Text-figure 39.
(x 3/5).

Text-figures 30-39.

Albula vulpes. Summary of the caudal skeleton development and corresponding change in body form from a 55 mm. leptocephalus to a 560 mm. adult. The five upper figures in the left column are natural size. Text-figure 35 is x 1/9.

occurs in specimens of the following lengths: 510, 403, 87, 47, and 36 mm. In two of these the double structure is on the next to the last, and in the other specimens it is on the last vertebra. This is not correlated with size, for in the other specimens of the series which are 560, 84, 40, and 22 mm., no double neural structure is present.

The comparative development of the skeleton is interesting in the series at hand. In the longest leptocephalus (55 mm.) the notochord is not yet segmented, nor has it taken up any alizarin (Text-fig. 36). In the successively shorter leptocephali more and more vertical lines appear at regular intervals which are the antecedents of the adult centra (Text-fig. 37). In all of the small specimens having the form of the adult, 22 mm. and larger, there is vertebral differentiation which is less distinct in the smallest specimen. Here the centra have not yet developed the shape of the adult centra. The vertebrae in the smallest specimens are rectangular and about twice as deep as wide (Text-figs. 21, 22). In all the small specimens there is ossification in the head and caudal regions. In the smallest fish of 22 mm. the only ossification of the notochord is in the caudal region, on the dorsal and ventral surfaces, near the bases of the neural and haemal spines.

It is consistent with the digging habits of *Albula* that one of the first areas of ossification should be the snout and head.

The first appearance of scales is in the 36 mm. specimen where they appear heavily stained. No scales are apparent on the 22 mm. fish.

The first appearance of ossification in the notochord is in the 22 mm. fish, and the urostyle segments are more definitely defined than in the younger intermediate 26 mm. specimen.

The dorsal fin-fold is absent for the first time in the 22 mm. specimen (Text-fig. 34).

It is interesting to note the rapidity of development which occurs between the 30.8 mm. leptocephalus and the 20 mm. young. In the *Albula*[3] that lived for ten days it took exactly six days to grow from 30 to 20 mm. It is just here during the life span of *Albula* that the unossified ribbon-like leptocephalus changes into an ossified, compact fish. In the shortening of the length the embryonic fin-folds disappear, the dorsal and anal fins and anus move forward (Text-figs. 32, 33, 34).

In the 26 mm. specimen, which is here termed an intermediate stage, change in the external shape of the body is more advanced than that of the internal and caudal skeleton, (Text-fig. 33). This resembles the 30.8 mm. leptocephalus more than the 22 mm. older form. In the 22 mm. fish the external body form resembles that of the adult (Text-figs. 34, 35). Again the development of the body is more advanced than that of the internal and caudal skeleton. In this stage is the first appearance of ossification around the notochord.

TABLE I.

Records of Extreme Lengths	Leptocephalus	Adult
From Literature	85 to 40 mm.	44 to 1220 mm.
From Bermuda Specimens	55 to 30.8 mm.	20[3] to 560 mm.
	Intermediate 26 mm.	

[3] This specimen is not cleared and stained, as it is the fish reared from a 55 mm. leptocephalus to a 20 mm. young *Albula*, where the body resembled the adult. It will be seen from the figures stated above in literature that this specimen probably is the smallest *Albula vulpes* in any collection. See the New York Zoological Society *Bulletin*, May-June 1936, Vol. XXXIX, No. 3.

DUSSUMIERIIDAE.

Jenkinsia lamprotaenia (Gosse).

(Text-figs. 40-44).

Diagnostic Characters:

7 hypurals.

1 reduced neural process. This is situated on the anterior part of the urostyle and, unlike *Elops* and *Tarpon,* it is forwardly directed.

3 distinct pairs of uroneurals.

Vertebral count: 27 + 16 = 43.

1 epural, the only isospondylid with one.

Prolonged bases of the two median caudal rays.

Total caudal ray count of 26, the smallest of the whole group.

Specialized neural processes unlike those of all other Bermuda isospondylids.

Material Studied.

This description is taken from the five following specimens and com-
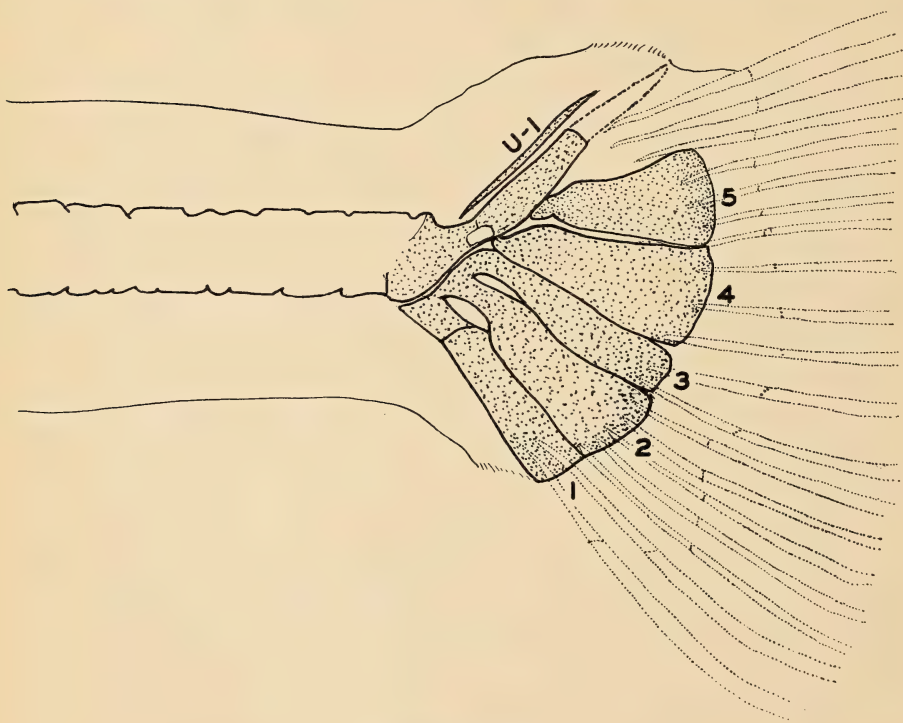
Text-figure 40.

Jenkinsia lamprotaenia. Tail of 10 mm. specimen with unossified and unsegmented vertebral column. There are only five hypurals and one pair of uroneurals ossified (x 140).

parative studies were made with fifty-five additional fish which range in size from young to adult.

Length	KOH Cat. No.	Text-fig. No.
40 mm.	2096	
26 mm.	343	44
18 mm.	657	43
15 mm.	657	42
11 mm.	657	41
10 mm.	657	40

Caudal Osteology.

Urostyle Centra: The adult urostyle appears as one bone. Anteriorly it is shaped like a half centrum and posteriorly it has a slender upturned end which is situated between the fourth and fifth hypurals, counting from the anterior. The distal end has projecting ventrally a fan-shaped bone that extends over the bases of the three dorsal hypurals, and covers an unossified area between the hypural bases and the end of the urostyle. In the young stages this bone is not present. It is first seen in an 18 mm. fish (Text-fig. 43). This space does not exist before the uroneurals appear and the urostyle has become fully ossified and reduced in size. In this stage the distal end of the urostyle and the bases of the hypurals almost meet (Text-fig. 43). With growth more and more space in this area appears. The urostyle is definitely divided into two parts in the young stages. The line of junction shows plainly in the adult (Text-fig. 44).
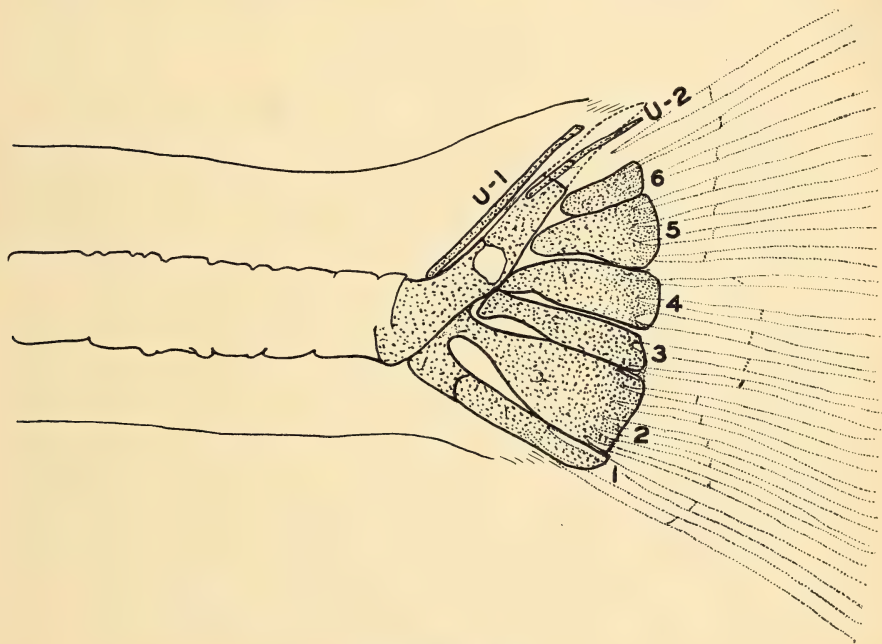
Text-figure 41.

Jenkinsia lamprotaenia. Tail of 11 mm. specimen with unossified and unsegmented vertebral column. There are six hypurals and two pairs of uroneurals ossified (x 108).
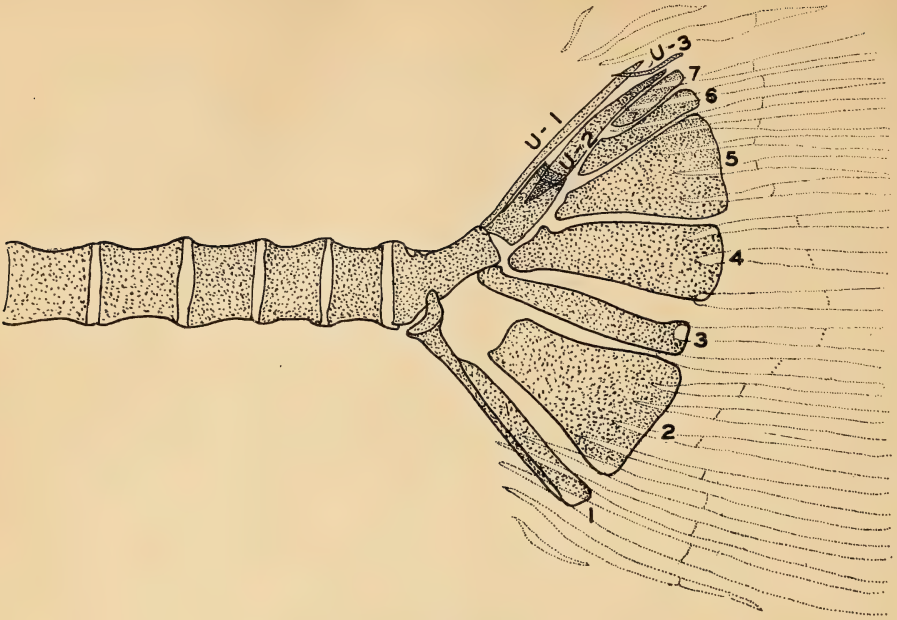
Text-figure 42.

Jenkinsia lamprotaenia. Tail of 15 mm. specimen with ossified and segmented vertebral column. There are seven hypurals and three pairs of uroneurals ossified. The basal end of the second hypural is reduced (x 64).
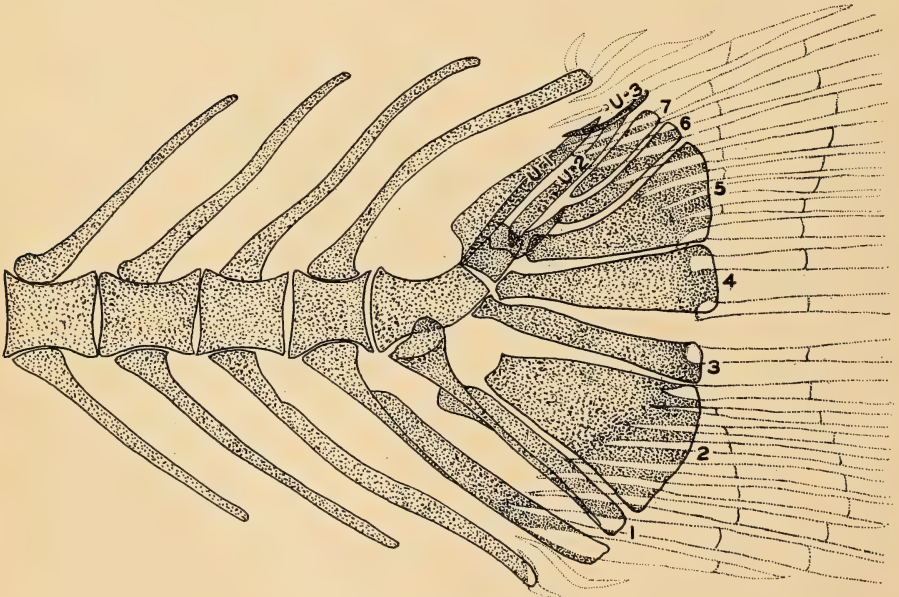
Text-figure 43.

Jenkinsia lamprotaenia. Tail of 18 mm. specimen with ossified neural and haemal processes (x 59).
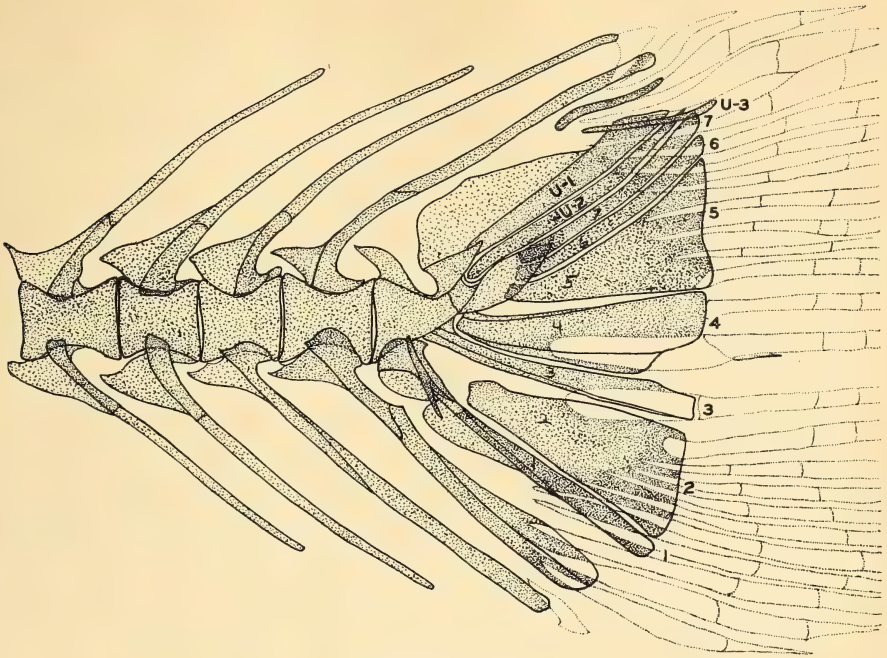
Text-figure 44.

Jenkinsia lamprotaenia. Tail of 26 mm. specimen with single epural ossified (x 39).

Uroneurals: There are three pairs of uroneurals in the adult. Each pair is quite different in shape, size, and general position, as may be seen in the accompanying drawings. The bones are numbered according to the order of their appearance. In several young stages the first pair appear as two separate bones which in the older stages fuse into a solid structure which is directly dorsal to the urostyle. It extends from the tip of the reduced adult urostyle into the caudal contour. In the older fish of 18 mm. and larger there is a median wing-shaped bone on the anterior three-fourths of the dorsal side. In specimens of 26 and 30 mm. this bone fills all the center of the unossified area which is between the posterior neural spine, the reduced neural process on the urostyle, and the epural.

The second pair of uroneurals first appears in the 11 mm. specimen. Here the two short lateral bones extend along the cartilaginous tip of the urostyle. In a 15 mm. specimen the bones are still separate but have enlarged in length and depth. In specimens of 18, 26, and 30 mm. the two bones are united. In each example the proximal ends overlap the tip of the ossified urostyle. The two bones of the diminutive third pair remain individual in all stages. They cannot be distinguished in a 11 mm. fish but in a 15 mm. specimen they are present. Their position is between the bases of the 10th and 11th dorsal caudal rays which are above the median line. There is a noticeable space in specimens of all lengths and here the cartilaginous prolongation of the notochard extends. The posterior ends of these bones arise beyond the caudal contour of the hypurals and extend obliquely forward and downward. (Text-figs. 41, 42).

The third pair of uroneurals is first seen in a 15 mm. specimen. This is the smallest of the three pairs, and the direction of the bones is more toward the anterior than that of the others. In the 15 mm. specimen the

position is between the dorsal tips of the first and second uroneurals with the anterior end of each bone crossing the end of the first uroneural. The posterior ends extend beyond the distal edge of the hypurals and occupy the area between the ray bases where the notochord extends. The accompanying drawings show the position and lengthening with growth (Text-figs. 42, 43, 44).

Hypurals: There are seven hypurals, three below and five above the median line. Two additional long haemal spines project into the caudal contour with fin-rays attached. In eleven young fish between the lengths of 10 and 13.44 mm., the second hypural is complete and the same length as the other hypurals. In twenty specimens between the lengths of 13.58 mm. and 40 mm., the base of the second hypural is reduced. It is entirely separate and free from the other hypurals and appears as a triangular island.

Epurals: There is only one epural in *Jenkinsia* which is first seen ossified in the 26 mm. fish. This bone can be seen in the smaller specimen but it is entirely unossified. *Jenkinsia* is the only Bermuda isospondyl having but one epural.

Specialized Neural Processes: In the completely ossified specimens of 26 mm. and larger there is a hook-shaped neural process on the posterior part of the urostyle. In the center of the urostyle this becomes very narrow and again expands posteriorly. The proximal end of the first uroneural is inserted between its tip ends. Dorsal to both is a thin median wing-like bone which is first seen in the 26 mm. specimen (Text-fig. 44).

Caudal Fin Ray Count:

26 mm.	$\dfrac{2 + 12 = 14}{1 + 11 = 12}$	(Text-fig. 44).
18 mm.	$\dfrac{3 + 11 = 14}{2 + 10 = 12}$	(Text-fig. 43).
15 mm.	$\dfrac{2 + 11 = 13}{1 + 10 = 11}$	(Text-fig. 42).
11 mm.	$\dfrac{}{10}$	(Text-figs. 41, 40).
10 mm.	$\dfrac{}{9}$	

Additional Characters Worthy of Note: In the fully ossified specimens of 26 mm. and larger the two median caudal rays have enlarged bases which project anteriorly half the length of the hypurals (Text-fig. 44). Among the Bermuda isospondyls this character is seen also in *Anchoviella* and the clupeids.

Enlarged wings on the anterior margin of the proximal ends of the haemal and neural spines are seen first in the 26 mm. specimen (Text-fig. 44).

In the youngest specimens vertebral ossification and individual vertebrae are first seen in 15 mm. fish. Here the urostyle, hypurals and caudal rays are well ossified. In the 10 mm. and 11 mm. specimens the vertebral column is not constricted and there is no ossification anterior to the urostyle.

According to caudal pattern and characters *Jenkinsia* seems to stand apart from the other Bermuda isospondyls. Conversely the three clupeids and *Anchoviella* are closely associated by similar patterns and characters.

ENGRAULIDAE.
Anchoviella choerostoma (Goode).
(Text-figs. 45, 46).

Diagnostic Characters:
    7 hypurals.
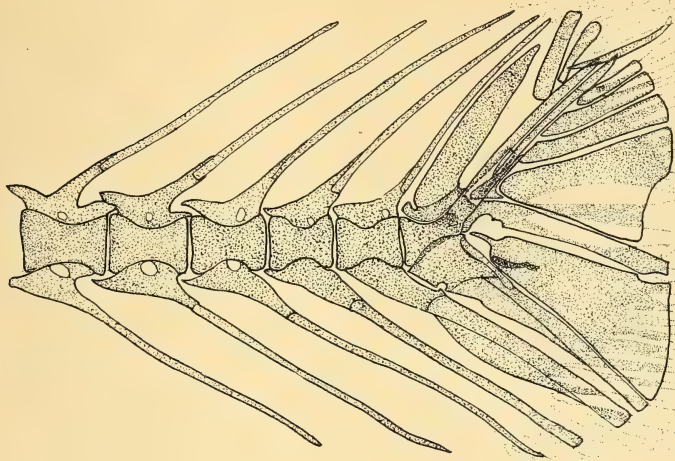
Text-figure 45.

Anchoviella choerostoma. Tail of 57 mm. specimen (x 11.5).

1 small reduced neural on the anterior base of the elongate neural process of the urostyle.

Vertebral count:

    20 + 20 = 40.   58 mm.
    21 + 20 = 41.   50 mm.
    21 + 21 = 42.   42 mm.

2 epurals and occasionally 2½.

Prolonged bases of the two median caudal rays.

Material Studied.

This description is based on twenty-nine specimens ranging in size from 20 to 59 mm. The 20 mm. fish is the smallest *Anchoviella* in our collection and is identical externally with the largest (59 mm.) fish. But the internal caudal development is not the same in the young specimen, which
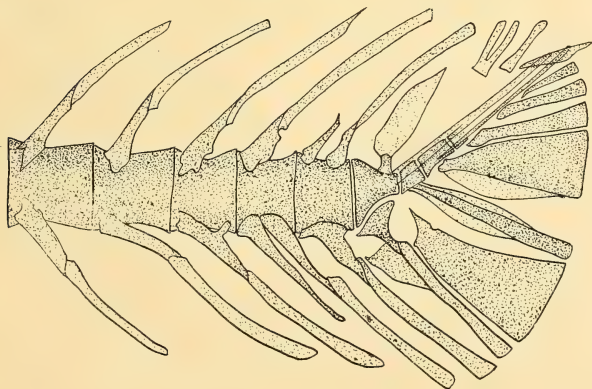
Text-figure 46.

Anchoviella choerostoma.
Tail of 20 mm. specimen
(x 28).

can be seen by the accompanying illustrations. The two specimens studied in particular are:

Length	KOH Cat. No.	Text-fig. No.
57 mm.	875	45
20 mm.	2095	46

Caudal Osteology.

Urostyle Centra: The interpretation of the adult urostyle is clarified by first studying the structure of the youngest specimen at hand. Here there are three distinct vertebral segments and the anterior part of a fourth is partly visible. (Text-fig. 46). In the large specimen, judging by the comparative position of the hypurals with that in the small fish, the two anterior segments fuse and the two posterior segments fuse. The posterior segment in the large specimen is further complicated by the presence of a small arch-like bone on the ventral side. This surrounds the proximal end of the fourth hypural. A similar structure is found in adults of the three clupeids.

Uroneurals: There are three pairs of uroneurals in the adult and the young specimen. The relative length, proximal and distal positions are the same in both fish. The anterior end of the pair that arises on the first urostyle centrum is not distinctly defined but there is little doubt that a smaller specimen would show the definite outline of the end of this bone.

Epurals: There are two and sometimes two and a half epurals in *Anchoviella*. The variation always occurs in the anterior bone which may be split in the form of a Y or have a hole in the center. This variation does not correlate with size. In fifteen specimens six have two epurals and the others have either the split or a hole in the anterior bone.

Specialized Neural Process: In the large specimens a long dagger-shaped bone extends from the anterior urostyle centrum to about the center of the anterior epural. In the 20 mm. specimen this bone is shorter and does not reach the basal end of the epural. This character, along with several others, distinguishes *Anchoviella* from the clupeids.

Caudal Fin Ray Count:

$$57 \text{ mm.} \quad \frac{5 + 13 = 18}{5 + 12 = 17}$$

In seven specimens out of fifteen, the caudal count is as stated above and is found in fish from 28 to 59 mm. In eight specimens there is variation in the total count from $\frac{17-19}{16-18}$. In the specimens examined the count of the dorsal and ventral is never $\frac{19}{16}$ as in the clupeids.

Clupeidae.

1. *Harengula* sp.

(Text-figs. 47, 48).

Diagnostic Characters:

7 hypurals.

1 reduced neural process. This process is insignificant and resembles the anterior neural zygapophysis.

3 pairs of uroneurals.

Vertebral Count: 12 to 14 + 25 to 26 = 37 to 40.

2 or 3 epurals.

Prolonged bases of two median caudal rays.
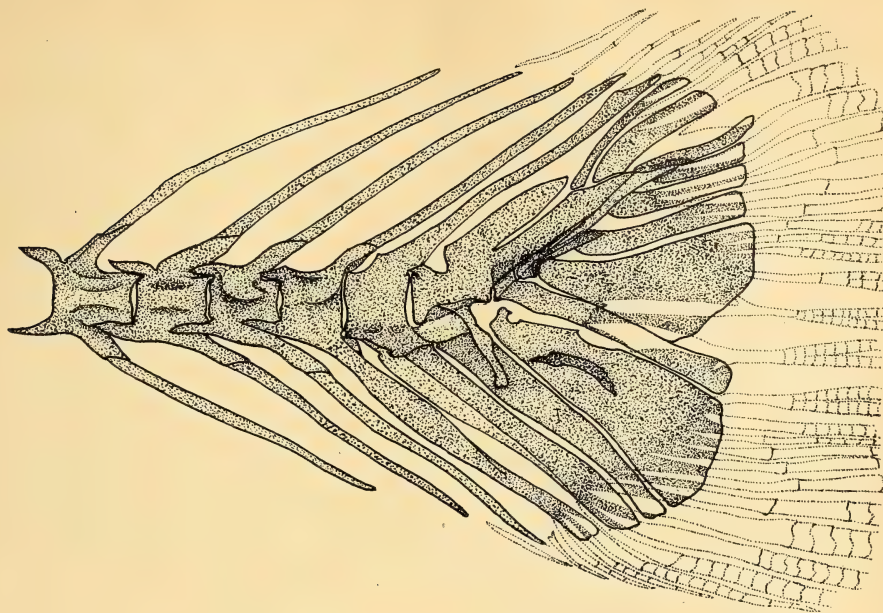
Text-figure 47.
Harengula sp. Tail of 165 mm. specimen (x 3.6).

Material Studied.

The KOH collection contains seventeen specimens ranging from 22 to 180 mm. The figure of the adult represents the tail structure of fish from 70 mm. to the largest. The illustration of the 22 mm. specimen, which is the smallest in the department collection, shows slight differences in degree of development. The two specimens studied in particular are the following:

Length	KOH Cat. No.	Text-fig. No.
165 mm.	847	47
22 mm.	656	48
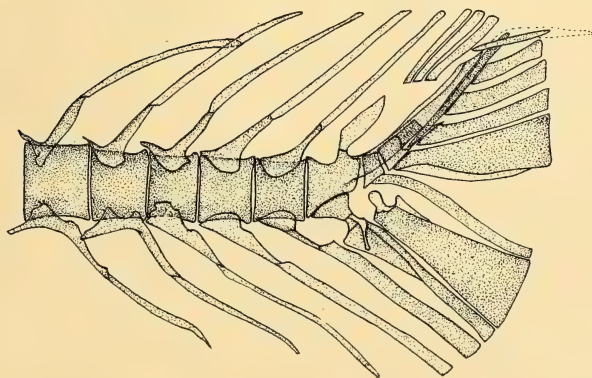
Text-figure 48.
Harengula sp. Tail of 22 mm. specimen (x 21).

Caudal Osteology.

Urostyle Centra: As in *Anchoviella,* the interpretation of the adult urostyle is best made by examining the youngest specimen (Text-fig. 48). Here, as in *Anchoviella,* there are four centra or vertebral segments in the urostyle. The anterior or first and second are separate but the third and fourth appear fused. In the adult all but the anterior or first segment have become comparatively reduced. The fourth cannot be seen under the heavy uroneurals. As in *Anchoviella* the first hypural is attached to the anterior urostyle segment and the third and fourth hypurals are attached to the second and third urostyle segment.

Uroneurals: As in Anchoviella there are three pairs of uroneurals in the adult and the young specimens. The illustrations show the relative size and position of these bones.

Epurals: There are two or three epurals in *Harengula.* In seven specimens ranging from 35 to 180 mm., I found two epural bones and in five fish ranging from 22 to 173 mm. there were three epurals. The variation of a split or perforated bone in *Anchoviella* has not been found in *Harengula.*

Specialized Neural Process: In the large specimen a stout dagger-shaped bone extends from the anterior urostyle segment as far as the basal end of the anterior epural. In the 22 mm. fish this bone is shorter (Text-fig. 48). In *Anchoviella* this bone extends beyond the end of the epural.

Caudal Fin Ray Count:

165 mm.	$1 + 18 = 19$	(Text-fig. 47).
	$1 + 15 = 16$	
40 mm.	$5 + 14 = 19$	
36 mm.	$4 + 12 = 16$	

In the specimens counted the dorsal and ventral combination was constant, 19/16, and never like that in *Anchoviella.*

Additional Characters Worthy of Note: The caudal pattern of *Harengula* is very like the two other Bermuda clupeids. In the number of *Harengula* specimens examined, only minor differences have been seen, such as the variation in the number of the epurals. This variation occurs in all the clupeids and in *Anchoviella.* Most Bermuda *Harengula* key to *sardina* as described in the "Field Book of the Shore Fishes of Bermuda," Beebe and Tee-Van.

2. *Opisthonema oglinum* (Le Sueur).
(Text-figs. 49, 50, 51).

Diagnostic Characters:

7 hypurals.

Small reduced pointed neural on the anterior of the urostyle.

Vertebral Count: $16 + 29 = 45.$

3 epurals.

Prolonged bases of two median caudal rays.

Material Studied.

This description is based on five specimens of the following lengths:

No. of specimens	Length	KOH Cat. No.	Text-fig. No.
2	110 mm.	850	
3	75 mm.	849	49, 50, 51
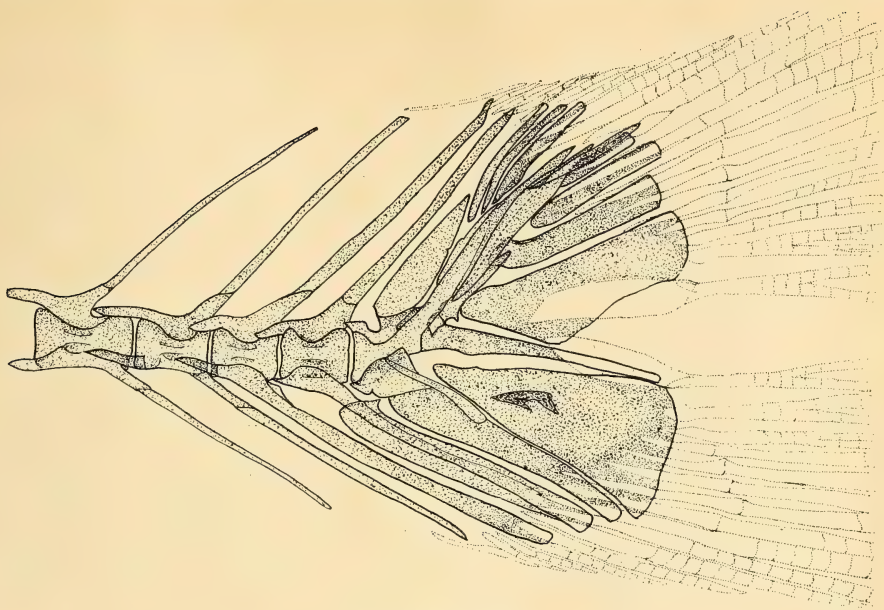
Text-figure 49.
Opisthonema oglinum. Tail of 75 mm. specimen (x 4.3).

These lengths represent the smallest and largest *Opisthonema* captured during our seven years in the field in Bermuda. The 75 mm. specimens are identical in development with the 110 mm. fish.

Caudal Osteology.

Urostyle Centra: This is very like *Harengula,* as the figures show. The dissection made by removing the superimposed uroneurals shows the adult elements of the urostyle. This condition is probably representative of all the Bermuda clupeids.

Uroneurals: The bones of the second pair of uroneurals are stout and noticeable heavier than those of *Sardinella* and *Harengula.* In other respects there is similarity between the three genera.

Epurals: There are three epurals found in the five specimens examined.
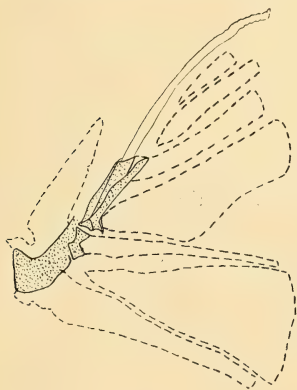
Text-figure 50.

Opisthonema oglinum. Tail of 75 mm. specimen dissected to show structure of the urostyle (x 3.7).
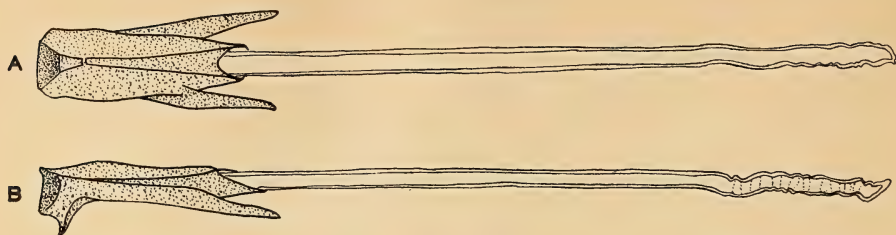
Text-figure 51.

Opisthonema oglinum. Last ossified segment of urostyle with cartilaginous notochord extending. A. View from the top; B. View from the side (x 8.5).

Specialized Neural Process: This stout neural bone is similar to that of *Sardinella* and *Harengula* in relative size and position.

Caudal Fin Ray Count: The count is identical with that of *Sardinella* and *Harengula*, 19/16.

Additional Characters Worthy of Note: In the specimens examined, *Opisthonema* differs from the other clupeids in the noticeably heavier second uroneurals and in the shape of the distal ventral surface of the fourth hypural, which is more or less even instead of having a sharp projecting point. The basal end of the second hypural is blunt instead of hammer-shaped as in *Sardinella*.

3.   *Sardinella anchovia* Cuvier and Valenciennes.
(Text-figs. 52, 53).

Diagnostic Characters:

> 7 hypurals.
> Small reduced blunt neural on the anterior part of urostyle.
> Vertebral Count: 14 or 15 + 31 or 32 = 46.
> 2½ or 3 epurals.
> Prolonged bases of the median caudal rays.

Material Studied.

Seven KOH specimens have been examined, which range in size from 32 to 135 mm. The caudal pattern is identical in specimens of 50 mm. and larger.

Length	KOH. Cat. No.	Text-fig. No.
60 mm. ⎱ 50 mm. ⎰	671	52
34 mm. ⎱ 32 mm. ⎰	2112	53

Caudal Osteology.

Urostyle Centra, Uroneurals: Almost identical with *Opisthonema* and *Harengula*.

Epurals: There are three epurals in the 32 and 34 mm. specimens. In the four larger specimens ranging from 50 to 135 mm., there are two and a half, the anterior bone being dorsally bifid. This variation is seen occasionally in *Anchoviella*.

Specialized Neural Process: This bone is almost the counterpart of that seen in *Opisthonema*.
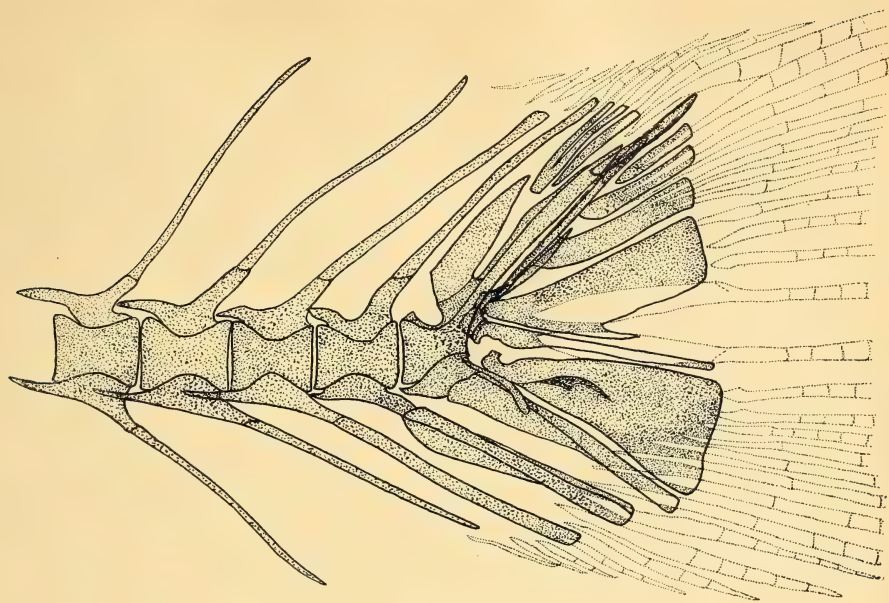
Text-figure 52.
Sardinella anchovia. Tail of 60 and 50 mm. specimens (x 28).

Caudal Fin Ray Count: As in *Opisthonema* and *Harengula,* the caudal count is 19/16.

Additional Characters Worthy of Note: The shape of the ventral distal edge of the fourth hypural differs from *Opisthonema* in that it has a sharp point. The basal end of the second hypural is hammer-shaped and this, too, differs from *Opisthonema.*

Summary.

The following paragraphs correlate the salient similarities and differences found in the study of the caudal skeletons of the Bermuda Isospondyli. According to caudal pattern and characters *Jenkinsia* seems to
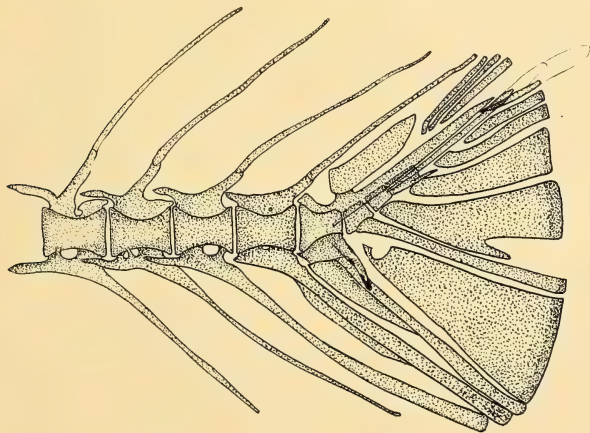
Text-figure 53.
Sardinella anchovia. Tail of 34 and 32 mm. specimens (x 16.5).

stand apart from the other Bermuda Isospondyli. Conversely, the three species of clupeids and *Anchoviella* are closely associated by similar patterns and characters.

Hypurals: In the first three families described, Elopidae, Megalopidae, and Albulidae, there is no noticeable deviation of the general pattern of the hypurals from that of *Leptolepis dubius,* which is the most primitive ancestor of the Isospondyli. All the hypurals are long, expanded haemal bones. But in the adults of all the other Bermuda Isospondyli the second hypural lacks the basal part and is a triangular bone with a reduced and free base. However in the few young specimens of *Jenkinsia* available for study the primitive, ancestral, unreduced, second hypural is present and resembles that of adult *Elops, Tarpon,* and *Albula.*

There are nine hypurals in *Elops,* eight in *Tarpon,* and seven in *Albula.* In the first two, where the urostyle is turned up less abruptly and the segments are less consolidated than in the other Bermuda Isospondyli, there are more hypurals. It will be seen in the figures of the key that *Elops* has one more hypural than *Tarpon,* which is numbered 0 (Text-figs. 3 & 4). Also that the dorsalmost hypural which is numbered 8 in *Tarpon* is not present in *Albula. Albula vulpes* and the other species described in this paper have seven hypurals. Hypurals with similar numbers correspond in position in all the specimens. (Text-fig. 5).

The following table correlates the hypural count in the various genera:

	Elops	*Tarpon*	*Albula*	All other Bermuda Isospondyli
Total hypurals	9	8	7	7
Dorsal hypurals	5	5	4	4
Ventral hypurals	4	3	3	3

Epurals: All Bermuda Isospondyli have more than one epural with the exception of *Jenkinsia* which has only one. This is the last bone to become fully ossified in *Jenkinsia.*

Caudal Ray Count: With growth and increase in size the dorsal and ventral raylets change into rays, resulting in a shift of relative numbers of the two elements.

In *Albula* the total caudal count of dorsal 18 and ventral 16 remains constant in specimens ranging from 36 to 560 mm. But the dorsal and ventral raylets diminish from 6 and 3 respectively to dorsal 1 and ventral 1, with a corresponding increase of rays.

Jenkinsia has the smallest caudal count of the Bermuda Isospondyli, which is a total of 26 as opposed to 30 or more in the other species.

The long functional caudal rays are present in *Albula* leptocephali and also in very small *Jenkinsia.* With growth, additional smaller anterior rays and raylets appear.

Prolonged Median Rays: In *Elops, Tarpon* and *Albula* there are no prolonged bases of the two median caudal rays. All the other Bermuda Isospondyli have these bases prolonged.

Ray-scale: The ray-scale which is prominent in *Elops, Tarpon* and *Albula* is less obvious in the remaining Isospondyli.

General Observations: The study of a series of young *Albula* and *Jenkinsia* show that development in the caudal region commences at the posterior extremity and progresses toward the anterior. Segmentation and ossification of the notochord begins in the urostyle region and the hypurals are the first bones to appear. The neural and haemal processes increase anteriorly with growth, the first to appear being near the urostyle. In

Jenkinsia the anterior-ventral hypurals appear first and with increase in size additional dorsal hypurals appear.

In *Albula* and *Jenkinsia* the caudal skeleton becomes ossified when the fish is very small and from this stage the changes that occur during growth are changes of degree and not of kind.

In *Tarpon* and *Elops* the last part to ossify is the area directly above the urostyle. This is filled by a preformed cartilage plate. In our two *Elops* specimens of 258 and 280 mm. there are two round islands of bone within this cartilage which indicate centers of ossification. Regan's specimen has a solid bone.

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*Names in **bold face** indicate new species; numbers in **bold face** indicate illustrations.*